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In August 1959, the President directed the Secretary of Health, Education, and Welfare, to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis, and interpretation of data on environmental radiation levels such as natural background, radiography, medical and industrial uses of isotopes and X rays, and fallout. The Department delegated this responsibility to the National Center for Radiological Health, Public Health Service.

Radiological Health Data and Reports, a monthly publication of the Public Health Service, includes data and reports provided to the National Center for Radiological Health by Federal agencies, State health departments, and foreign governmental agencies. Pertinent original data and interpretive manuscripts are invited from investigators. These are subject to review by a Board of Editorial Advisors with representatives from the following Federal agencies:

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service ● National Center for Radiological Health

Reports

RADIONUCLIDE LEVELS IN MILK, TOTAL DIET, AND HUMAN BONE COMPARED TO FEDERAL RADIATION COUNCIL ESTIMATES, 1965, AND 1966 ESTIMATES

Standards and Intelligence Branch
National Center for Radiological Health [1]
Public Health Service

Estimates of the levels of fallout radionuclides in environmental media and in human bone expected from 1963 through 1965 have been made by the Federal Radiation Council. The 1965 observed values are compared with the FRC predictions and 1966 levels are estimated using the approach proposed by the Federal Radiation Council. The observed radionuclide levels are in agreement with the prediction made by the Federal Radiation Council. The observed levels and the predicted levels of radioactivity in food over the next several years are too small to justify protective action to limit the dietary intake of radionuclides.

The Federal Radiation Council (FRC) has made estimates of the levels of fallout radionuclides in environmental media and in human bone expected from 1963 through 1965 from atmospheric testing of nuclear weapons conducted through 1962 (*1,2*). Observed values for 1963 and 1964, based on surveillance measurements, were presented earlier and compared to these predictions (*3*). Discussion was centered on those ingested fallout radionuclides most significantly contributing to the internal radiation dose to man: strontium–89, strontium–90, iodine–131, and cesium–137. This paper compares the 1965 observed values with the FRC predictions and, using the approach taken by FRC, estimates 1966 levels.

Milk

While total diet measurements yield the most direct estimate of radionuclide intakes, specific indicator foods are also important. The single food item most often used as an indicator of the population's intake of radionuclides from the environment is milk. At the same time, milk is often the most rapid food vector by which man can be exposed. Milk contains most of the radionuclides occurring in the environment which have been identified as biologically significant, and is consumed by a large segment of the U.S. population.

The Public Health Service's Pasteurized Milk Network (PMN) monitors radionuclide concentrations at 63 sampling locations in selected U.S. municipalities and is the primary source of data for radioactivity in milk used in this article (*4*). Additional information on radionuclide concentrations in milk is obtained through the Atomic Energy Commission's Tri-City Diet Study (*5*) and through various State milk-sampling programs. With the resumption of atmospheric testing in late 1961, a general increase in average monthly radionuclide concentrations in milk was observed by the PMN (*6*).

Strontium–89. Noticeably increased strontium–89 activity in milk was exhibited in the spring of 1962 and 1963. However, concentrations of this radionuclide declined after the spring of 1963, becoming negligible by the spring of 1964 (*3*).

Strontium–90. The observed strontium–90 concentrations in milk from the PMN for the period 1960 through 1965 are presented graphically in figure 1. The average monthly concentration showed a general increase during 1962

[1] Prepared by Richard D. Grundy, senior technical editor, *Radiological Health Data and Reports.*

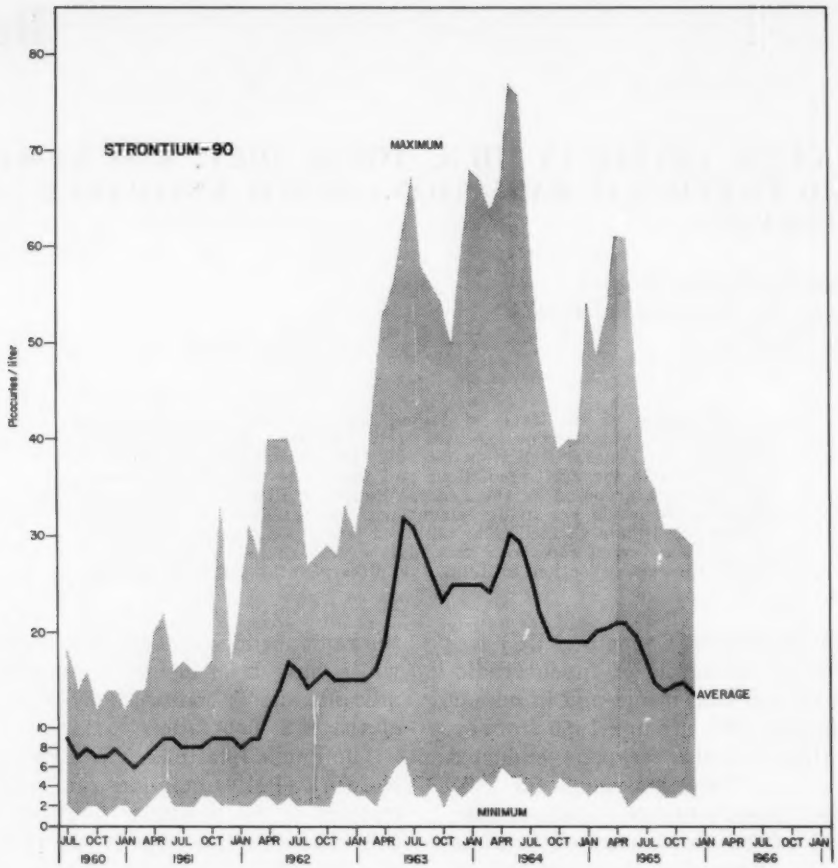

Figure 1. Average, maximum, and minimum concentrations of strontium–90 in milk from the Pasteurized Milk Network

and exhibited peaks in 1963 and 1964. Subsequently, the concentration of strontium–90 in milk declined.

For comparison with the FRC data (*1,2*), these concentrations, along with data obtained by the Tri-City Diet Study (*5*), are presented on a "wet" and "dry" are basis in table 1. It is observed that in the "wet" area, data produced by the two programs were in close agreement. In 1963, the PMN results were slightly below the FRC predictions.

In 1964, the results of both programs were slightly below the predicted concentration. Although not striking, this difference suggested that 1965 predictions might be (and were)

Table 1. Annual average strontium-90 content of U.S. milk 1961–1965, compared with Federal Radiation Council estimates for 1965 and estimates for 1966

Year	Strontium-90 content (pCi/g Ca)					
	"Wet" area [a]			"Dry" area [a]		
	New York (Tri-City)	PMN	Estimate	San Francisco (Tri-City)	PMN	Estimate
1961	10	10	—	5	5	—
1962	15	15	—	5	10	—
1963	30	25	[a] 30	10	15	[a] 10
1964	25	25	[b] 30	10	15	[b] 10
1965	15	20	[b] 25	10	10	[b] 5
1966	—	—	[c] 20	—	—	[c] 10

[a] Stated in Federal Radiation Council Report No. 4.
[b] Stated in Federal Radiation Council Report No. 6.
[c] Estimated herein using the approach employed in Federal Radiation Council Reports Nos. 4 and 6, and rounded to the nearest 5 pCi/g Ca.

somewhat high (*3*). Table 1 indicates that environmental contamination in 1965 was not as great as predicted for the "wet" area.

Considering the "dry" area, the Tri-City Diet Study milk results for 1963 and 1964 were in agreement with the FRC predicted concentrations. However, PMN results for 1964 and 1965 were slightly higher than the predicted concentrations. Compared to the 1965 predictions, results from both programs were somewhat high.

Predictions of 1966 levels have not been made by the FRC. However, predictions of strontium–90 content of milk can be made on the basis of strontium–90 depositions and the strontium–90 content of soil (*7,8*). Such estimates have been made by previous investigators *(9–11)* and employed by the FRC *(1,2)* on the basis of the following equation:

$$M = aS + bR \quad (1)$$

where M = strontium–90-to-calcium ratio in milk (pCi/g),

S = cumulative deposition of strontium–90 in the soil (mCi/mi^2),

and R = average monthly strontium–90 fallout rate (mCi/m^2) month.

The proportionality constants, "a" and "b" developed on the basis of New York City's results *(10)* are:

$$a = 0.1 \times 10^{-9} \text{ mi}^2/\text{g Ca } (8)$$
$$b = 4.7 \times 10^{-9} \text{ mi}^2/\text{g Ca } (8).$$

Thus, to predict the average annual strontium–90-to-calcium ratio in "wet area" milk, the following equation is used:

$$M = 0.1\ S + 4.7\ R \quad (2)$$

The accumulated deposition of strontium–90 in the United States through 1963 in the "wet" area was 150 mCi/mi^2 *(2)*, while 1964 and 1965 depositions were 41 and 15 mCi/mi^2, respectively (*9*). Thus, the accumulated deposition through 1965 was 206 mCi/m^2.

On the basis of the observed decrease in fallout deposition, it was estimated that 1966 strontium–90 deposition (R) would approximate 4 mCi/mi^2 (0.33 mCi/m^2 • month). Using these "wet-area" figures, the 1966 strontium–90 concentration in milk can be estimated from equation (2) as 22 pCi/g calcium.

The same approach can be applied to the estimation of 1966 levels for the "dry area." Accumulated deposition of strontium–90 through 1963 was 65 mCi/mi^2. The 1964 and 1965 depositions in San Francisco, representative of the "dry area", were 7.5 and 5.4 mCi/m^2, respectively, for an accumulated deposition of 78 mCi/mi^2 through 1965 *(10)*. On the basis of the observed strontium–90 depositions, it is estimated that 1966 deposition will approximate 3 mCi/m^2 (0.25 mCi/mi^2 • month). Using these "dry-area" figures, the 1966 strontium–90 concentrations in milk can be estimated as 10 pCi/g calcium. This is higher than the FRC 1965 estimate of 5 pCi/g calcium, which was lower than the 10 pCi/g calcium actually experienced.

Iodine–131. During 1965, iodine–131 concentrations in milk from the PMN averaged less than 10 pCi/liter. Occurrence of iodine–131 in milk since 1961 has been limited to periods immediately following the first *(12)* and second *(13)* Chinese atmospheric nuclear tests (figure 2). As predicted, iodine–131 in milk became undetectable by mid-1963 (*2*). Since the beginning of the program in 1961, the peak annual average was 104 pCi/liter. This peak occurred in 1962 at Palmer, Alaska. Using the assumption of 1 liter daily intake of milk, this annual average would correspond to Range III (100 to 1,000 pCi/day) as defined by the FRC *(14)*.

Cesium–137. Cesium–137 concentrations in milk paralleled the strontium–90 results. A continued increase was observed from 1961 through 1964, when the peak concentrations of cesium–137 in milk occurred (figure 3). Subsequently, levels decreased through 1965. The annual averages in 1965 were 61 pCi/liter in the "wet" area, and 46 pCi/liter in the "dry" area.

Diet

Estimates of children's and teenagers' radionuclide intakes have been obtained since 1961, from the Institutional Total Diet Sampling Network *(15)* of the National Center for Radiological Health and the National Center for Urban and Industrial Health. This network, the Atomic Energy Commission's Tri-City Diet Study (*5*), and the Food and Drug Administration's Teenage Diet Survey *(16)* provide nationwide estimates of dietary intake of radio-

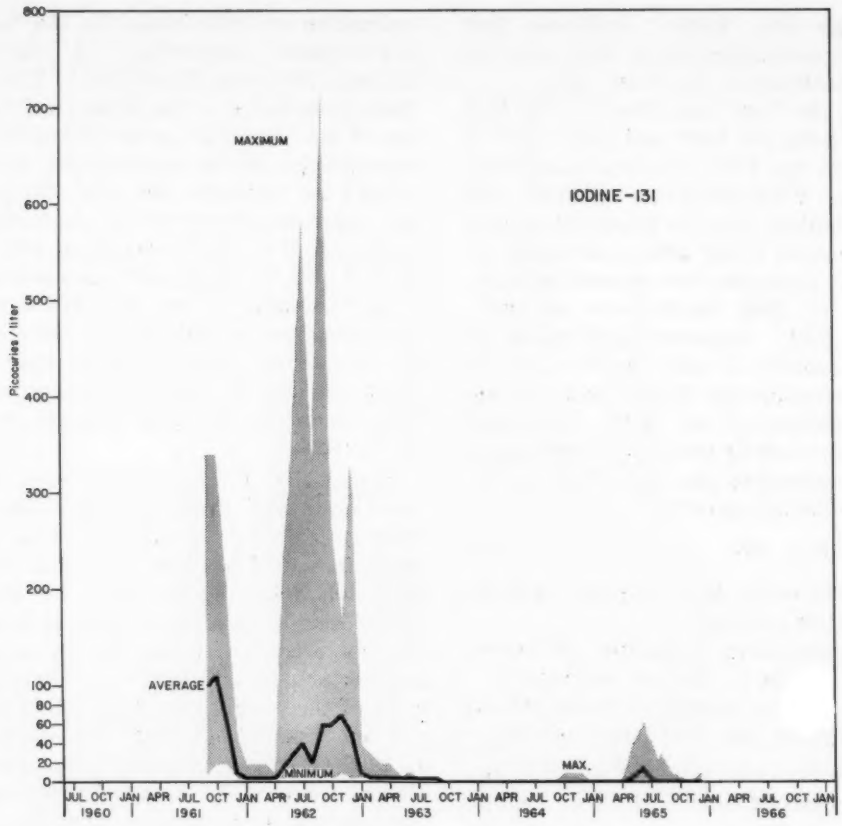

Figure 2. Average, maximum, and minimum concentrations of iodine–131 in milk from the Pasteurized Milk Network

nuclides. The characterization of radionuclide concentrations in the diet constitutes an important element of any population-oriented radiological surveillance program.

Strontium–89. Increased levels of strontium–89 in the diet were observed in the Institutional Diet samples in late 1961, following the resumption of atmospheric nuclear testing *(17)*. The average daily intake reached peaks in mid-1962 and 1963, and declined thereafter (*3*). Concentrations of this radionuclide in the diet diminished to negligible levels by early 1964. The annual average daily intake was approximately the same in mid-1962 and mid-1963. These observations were in agreement with FRC predictions (*1*). The maximum annual average strontium–89 intake at any institution during this period was 182 pCi/day in 1963 (*4*). Except for a few isolated instances immediately following the first and second Chinese atmospheric nuclear tests, strontium–89 concentrations during 1965 remained below detectable levels.

Strontium–90. Unlike strontium–89, strontium–90 has been observed in the Institutional Diet samples continuously since the inception of the network in 1961. After the resumption of nuclear testing in 1961, the average daily intake increased steadily, reaching a maximum in the spring of 1964 (figure 4). The network annual average intakes were 13 pCi/day in 1962; 25 pCi/g Ca in 1963; and 32 pCi/day in 1964, corresponding to approximately 12, 22, and 28 pCi/day, respectively.[2]

During 1965 the network annual average was 28 pCi/day, corresponding to 25 pCi/g calcium. The observed decreasing trend is ex-

[2] Based upon an intake of 1.13 grams of calcium per day (*17*).

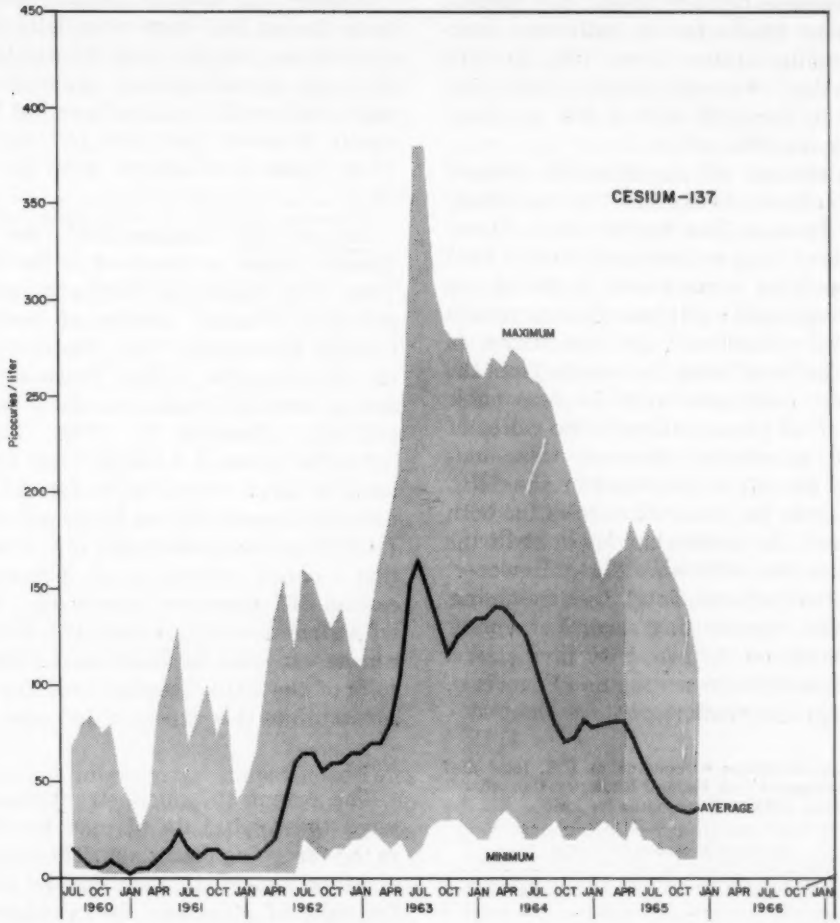

Figure 3. Average, maximum, and minimum milk concentrations of cesium–137 in the Pastuerized Milk Network

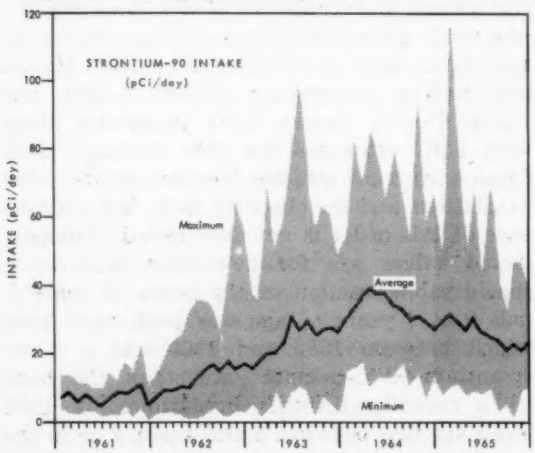

Figure 4. Monthly average strontium–90 intakes and ranges in Institutional Total Diet Sampling Network

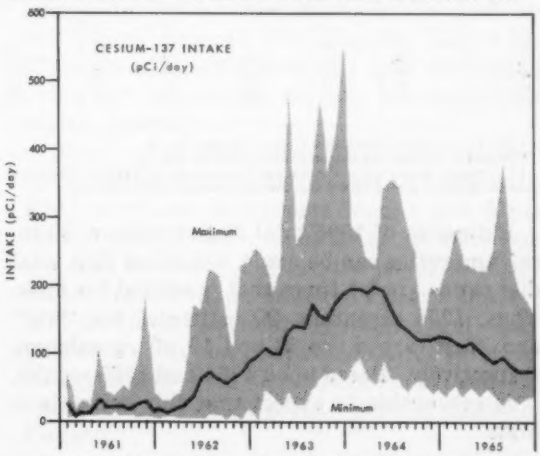

Figure 5. Monthly average cesium–137 intakes and ranges in Institutional Total Diet Sampling Network

pected to continue through 1966. The highest annual average intake for an individual institutional sampling station from 1961 to 1965 was 48 pCi/day, observed during 1964. This corresponds to Range II (20 to 200 pCi/day) as defined by the FRC *(14)*.

Similar patterns of strontium–90 dietary intake were reflected in the Tri-City Diet Study *(5)* and the Teenage Diet Survey *(16)*. Strontium–90 dietary intakes increased during 1961 and 1962, reaching a maximum in the spring of 1964. Comparisons of these dietary results with the FRC estimates *(1,2)* are shown in table 2. For the "wet" area, the results from the two sampling programs were in reasonable agreement for all years, although the ratios of strontium–90 to calcium observed were uniformly below the values predicted by the FRC. In the "dry" area the observed results for both programs were also somewhat lower than the predicted ratio for 1963 and 1964. However, in 1965 the Institutional Total Diet Sampling Network result, representing several sampling locations, was higher than the FRC predictions. The Tri-City result, representing San Francisco, was lower than the prediction.

Table 2. Average strontium-90 content of U.S. total diet 1961–1965, compared with Federal Radiation Council estimates, 1965, and estimates for 1966

Year	Strontium-90 content (pCi/g Ca)					
	"Wet" area[a]			"Dry" area[a]		
	New York (Tri-City)	Institutional diet	Estimate	San Francisco (Tri-City)	Institutional diet	Estimate
1961	5	10	—	5	5	—
1962	10	10	—	5	10	—
1963	30	25	[a] 50	10	15	[a] 35
1964	30	30	[b] 40	10	20	[b] 20
1965	20	20	[b] 30	10	20	[b] 15
1966	—	—	[c] 30	—	—	[c] 15

[a] Stated in Federal Radiation Council Report No. 4.
[b] Stated in Federal Radiation Council Report No. 6.
[c] Estimated herein using the approach employed in Federal Radiation Council Reports Nos. 4 and 6 and rounded to nearest 5 pCi/g Ca.

Estimates of 1966 total diet strontium–90-to-calcium ratios can be made, assuming that total diet ratios are 1.5 times that predicted for milk. Thus, 1966 strontium–90 estimates for "wet" and "dry" areas are 30 and 15 pCi/g calcium, respectively. Based upon 1964 and 1965 results, it is reasonable to expect that this estimate is high.

Iodine–131. Annual average iodine–131 intakes during 1965 were essentially zero. Except for isolated samples immediately following the first and second Chinese atmospheric nuclear tests, iodine–131 intakes have not been significantly different from zero pCi/day since mid–1963, which is consistent with the predictions *(2)*.

Cesium–137. During 1965, the cesium–137 dietary intake, as observed in the Institutional Total Diet Sampling Network, averaged 105 pCi/day. Dietary intakes of cesium–137 decreased throughout 1965 (figure 5) paralleling the strontium–90 intake. Since 1961, the peak annual average intake on a daily basis was 154 pCi/day, observed in 1964. This is well below the value of 4,400 pCi/day for the population at large, which can be derived from International Commission on Radiological Protection (ICRP) recommendations *(18)*. Federal Radiation Council estimates of dietary intake of cesium–137 have not been made. However, as with strontium–90, cesium–127 dietary intakes can be expected to decrease during 1966. Results of the FDA Teenage Diet Survey further substantiate this expected decrease *(16)*.

Bone

The extent to which strontium–90 has entered the food chain of man has been shown in the foregoing discussion. The resultant levels of strontium–90 in man can be described by the ratio of strontium–90 to calcium in bone.

For consistency with the presentation in FRC Reports Nos. 4 and 6, the 0- to 4-year-old age group is considered. Table 3 shows the observed strontium–90-to-calcium ratios in bone from 1958 to 1965 for the AEC's Health and Safety Laboratory (HASL) (*19*) and Public Health Service (*20*) programs, along with FRC estimates for 1963 through 1965. Close agreement was not obtained between the predictions and the observed data, but a difference of this order is not unexpected. The predicted values are for new bone, whereas a considerable fraction of the bones of individuals 0 to 4 years of age was preformed bone which between 1963 and 1965 had a lower strontium–90-to-calcium ratio than the bone more recently formed. Predictions of 1966 levels for new bone are 8 and 4 pCi/g ca in the

"wet" and "dry" areas, respectively, based upon the FRC assumption that one-fourth of the dietary concentration of strontium–90 is deposited in new bone and that the strontium–90-to-calcium ratio in old bone is the same as in new bone.

Table 3. Average strontium-90 content of human bone in the United States, for 0- to 4-year olds at death 1958–1965

Year	Strontium-90 content (pCi/g Ca)					
	"Wet" area			"Dry" area		
	Estimated [a]	Observed		Estimated [a]	Observed	
		HASL	PHS		HASL	PHS
1958		2.0			2.0	
1959		2.7			2.2	
1960		2.4			1.8	
1961		2.6			0.9	
1962		3.1	3.2		1.1	
1963	12	5.0	4.8	9	1.9	
1964	10	6.0	3.4	5	2.7	2.7
1965	8	6.2	4.4	4	3.1	2.3
1966	[b] 8			[b] 4		

[a] 1963, 1964, and 1965 values are predicted by assuming one-fourth of the dietary level of strontium-90 is deposited in new bone in 0- to 4-year-old children *(1,2)*, and assuming that the strontium-90-to-calcium ratio of old bone in this group is the same as that of new bone.
[b] Estimated herein using the approach employed in FRC Report Nos. 4 and 6.

Estimated dose

It is possible to estimate annual dose rates to children from the observed strontium–90 in bone and cesium–137 concentrations in milk. The resultant radiation dose rate from the indicated strontium–90 concentrations in bone may be estimated from the dose conversion factor presented by the FRC *(21)*. Thus the highest average bone level shown, 6.2 pCi/g calcium in 1965, would result in a dose rate to bone marrow of approximately 5.5 millirad in 1 year.

For cesium–137, the yearly dose (assuming equilibrium) can be calculated from the following:

$$D = (11)\frac{I}{W}\,1.44T_e \qquad (3)$$

where

D = dose (rads),
11 = conversion constant (kg-rads/μCi-day),
I = daily intake of cesium–137 (μCi/day),
W = body weight (kg),
and T_e = effective half-life (days).

For infants, the effective half-life is taken to be 30 days, and the body weight as 10 kg *(21)*; also, it is assumed that 1 liter is the daily intake of milk. For the "wet" area, with a 1965 average for cesium–137 in milk of 105 pCi/liter, the resultant dose rate would be approximately 5.2 millirad for the year. Since both strontium–90 and cesium–137 contribute to bone-marrow dosage, the sum of the estimated doses is of significance *(21)*; thus, the estimated total dose rate to bone marrow would be approximately 11 millirad during 1965 for young children in the "wet" area.

For long-term low-level situations, such as are represented by these data, specific guidance has not been recommended by the FRC. Rather, annual doses from fallout equal to, or greater than, the numerical values of the Radiation Protection Guides (RPG's) can be used as an indication of when there is a need for careful evaluation of fallout exposures. The RPG for total bone for the general population is given as 500 mrad/year *(14)*. Thus, in the above case, the dose rate owing to strontium–90 and cesium–137 for young children in the "wet" area amounts to approximately 2 percent of the RPG.

Summary

The estimates made in FRC Reports Nos. 4 and 6 regarding the average concentrations of radionuclides in the environment and man for 1965 have been essentially verified by the 1965 surveillance data. The peak intake of radionuclides by the population groups selected occurred in 1964. The conclusion is that the predictions made in FRC Reports Nos. 4 and 6, and the projected radiation dose rate appear valid and reasonable for the situation as it exists currently.

Based upon predictions of dietary contamination levels in 1963 and subsequent years, the FRC concluded in Reports Nos. 4 and 6 that health risks from radioactivity in food over the next several years are too small to justify protective actions to limit the dietary intake of radionuclides, particularly milk and dairy products. The observed radionuclide levels are in agreement with these predictions and substantiate conclusions of the Federal Radiation Council.

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STRONTIUM-90 DIETARY INTAKE ESTIMATES BASED ON FRACTIONAL INTAKES DUE TO MILK

Richard D. Grundy [1]

Strontium–90 dietary intake estimates were made for the Institutional Total Diet Sampling Network based upon Pasteurized Milk Network concentrations. Approaches based upon milk-to-total-diet ratios of strontium–90 and strontium units were considered. The approach based upon strontium units yielded the best estimates of ITDSN monthly average and maximum strontium–90 intakes on a network basis for the population groups involved.

The Federal Radiation Council (FRC) stresses the determination of internal exposures to man from environmental radiation sources, particularly from radionuclides in the diet. While the more accurate measure of intake is through total diet measurements, indicator foods have been proposed to estimate dietary intakes of such radionuclides as strontium–90.

Fresh whole milk representing the major source of calcium in the diet, has been suggested as such an indicator food. As a result of its high consumption rate in the United States, milk and milk products represent the largest single source of strontium–90 intake. However, milk contains a lower level of strontium–90 per unit calcium[2] than the average for the non-milk portion of the diet. This lower level is due to discrimination in favor of calcium over strontium in the cow's metabolic processes.

Further discrimination in man's metabolic processes results in a decrease in the strontium–90-to-calcium ratio to the extent that this ratio in bone is about one-fourth of the strontium-calcium ratio in the total diet (*1*). As a result of the two-stage process (cow-milk-man), strontium unit levels are lower for those segments of the population with the same average diet, but with lower milk consumption (*2*). Although the fallout levels in the Southern Hemisphere are an order of magnitude lower than in the Northern Hemisphere, the bone levels of strontium–90 in the United States are about double those found in the primarily plant-consuming cultures located in equatorial and Southern Hemisphere portions of the world (*2*).

This paper presents, on a national basis, an analysis of the fractional intakes of strontium–90 resulting from milk for the population group represented by the ITDSN. An attempt was made to evaluate the use of milk strontium–90 concentrations and strontium–90-to-calcium ratios to estimate dietary intakes for the conterminous United States.

Evaluation on an individual station basis was not feasible at this time because of the limited number of samples available. For the purpose of this presentation, levels in milk were related to those in the total diet (including milk). In this manner, a fractional intake (or percent of intake) due to milk was obtained. The data used were from the Public Health Service's Institutional Total Diet Sampling Network and Pasteurized Milk Network (PMN) for the period 1963 through 1964. Ratios were calculated using both strontium–90 concentrations in milk and total diet and strontium unit values. The results are presented below. It should be noted that the ratios developed are the reciprocal of ratios cited by previous investigators based upon observed and/or assumed milk intakes (*2–5*).

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[2] A common term for expressing strontium–90-to-calcium ratios in milk, total diet, and bone is "strontium units." It is expressed in picocuries of strontium–90 per gram of calcium.

Strontium–90 dietary intakes

At the present time, ITDSN stations are collecting monthly total diet samples which are analyzed for calcium, strontium–90, and other selected radionuclides. The results define the dietary intake of strontium–90 for the population group represented by the Institutional Total Diet Sampling Network. The observed results indicate that, during the first 8 months of 1961, the average strontium–90 intake was 8 pCi/day. With the resumption of atmospheric nuclear testing in the fall of 1961, a steady increase was observed until April 1964 at an annual rate of approximately 10 pCi/day (*6*). At that time a decreasing trend ensued upon which was superimposed the expected seasonal variation involving a spring rise. Currently, dietary intakes of strontium–90 are within Range II (20–200 pCi/day) as defined by the FRC (*1*). Maximum dietary intakes have remained below 100/pCi day at all times. At these levels, the FRC requires quantitative surveillance and routine control (*1*).

Fractional intakes of strontium–90

In order to determine milk fractional intakes of strontium–90, it is necessary to know the actual weights of milk and non-milk portions of the diet. Although routine ITDSN reporting procedures report total dietary consumption values, milk consumption weights are obtained at the time of sample collection and are available.

Since it was proposed to use PMN milk results in conjunction with ITDSN total diet results, it was necessary to determine the validity of interrelating results from these networks. Evaluation was made for the period July 1963 through May 1964. During this period the ITDSN separately collected and analyzed the milk and non-milk portions of the diet. For routine reporting purposes, results were then combined to obtain ITDSN total strontium–90 intakes. In a similar manner PMN milk results were used in place of ITDSN milk results, and the resultant strontium–90 intakes calculated as a basis for further calculations as presented herein.

Evaluation of the two methods of calculating strontium–90 fractional intakes was performed by first calculating, on the basis of individual ITDSN station results, the monthly fractional intakes of strontium–90 resulting from ITDSN milk [MTD $(^{90}Sr)_I$] as follows:

$$\text{MTD } (^{90}Sr)_I = \frac{Con_m \cdot Sr_m \text{ (ITDSN)}}{Con_d \cdot Sr_d} \qquad (1)$$

where

Con_m = milk consumption (kg/day), monthly ITDSN value,

Sr_m (ITDSN) = strontium–90 concentrations in milk (pCi/kg), monthly ITDSN value,

Con_d = total diet consumption (kg/day), monthly ITDSN value,

and

Sr_d = strontium–90 concentration in total diet, (pCi/kg), monthly ITDSN value.

On the basis of 123 monthly station results, a mean milk fractional intake of strontium–90 of 0.54 was observed, with a standard deviation of 0.17. It should be emphasized that to obtain this ratio, it was necessary to perform monthly analyses on both the milk and non-milk fractions of the total diet. On a routine basis, this serves no practical advantage, since a single analysis on the total diet sample would have provided the desired strontium–90 intake figures.

Milk monthly fractional intakes of strontium–90 were then calculated using PMN sample results. If possible, PMN stations and ITDSN stations were selected within the same municipality. Where this was not feasible the nearest sampling station within the same State was selected. The resultant milk fractional intakes [MTD $(^{90}Sr)_P$] were calculated using equation (2):

$$\text{MTD } (^{90}Sr)_P = \frac{Con_m \cdot Sr_m \text{ (PMN)}}{Con_d \cdot Sr_d} \qquad (2)$$

where

Sr_m (PMN) = strontium–90 concentration in milk (pCi/kg), monthly average PMN value.

On the basis of 418 monthly ratios for 1963 and 1964, a mean milk fractional intake of 0.58 was observed, with a standard deviation of 0.22. The MTD ratios using both ITDSN and PMN strontium–90 concentrations in milk and

ITDSN total diet strontium–90 concentrations are summarized in table 1.

Assuming "normal" distribution of the ratios, the results of the two methods of calculation were statistically compared on the basis of a test as follows:

$$Z = \frac{\text{MTD } (^{90}\text{Sr})_P - \text{MTD } (^{90}\text{Sr})_I}{\sqrt{\frac{\sigma_I^2}{\eta_I} + \frac{\sigma_P^2}{\eta_P}}} \qquad (3)$$

$$Z = 2.17 > Z(0.05) = 1.64$$

It was apparent from the test that the observed means of the two methods were statistically different at the 5-percent level of significance. Therefore, before attempting to use the approach based upon strontium–90, the strontium unit (strontium–90-to-calcium ratio) approach was investigated.

Table 1. Fractional dietary intakes of strontium-90 resulting from milk

	MTD $(^{90}Sr)_I$	MTD $(^{90}Sr)_P$
Number of samples (n)	123	418
Mean	0.54	0.58
Standard deviation (σ)	0.17	0.22
90-percent confidence interval ($\pm 1.64\sigma$)	0.26 to 0.82	0.22 to 0.94

Strontium–90-to-calcium ratio approach

Strontium–90 is similar to calcium biochemically, and the metabolism of strontium is linked to the metabolism of calcium in a complex way (*1*). Although the body preferentially absorbs calcium and preferentially excretes strontium, both are incorporated into new bone in the same ratio as they exist in blood (*1*).This metabolic similarity makes it useful to consider ratios of these two elements when evaluating dietary intakes of strontium–90.

Using the monthly ITDSN results, milk-to-total-diet ratios of strontium units [MTD $(SU)_I$] were calculated on an individual station basis for the period of July 1963 through May 1964, as follows:

$$\text{MTD } (SU)_I = \frac{Sr_m \text{ (ITDSN)} \cdot Ca_d}{Ca_m \text{ (ITDSN)} \cdot Sr_d} \qquad (4)$$

where

Ca_m (ITDSN) = calcium concentrations in milk (g/kg), monthly ITDSN value,

and Ca_d = calcium concentration in total diet (g/kg), monthly ITDSN value.

On the basis of 143 monthly values, a mean strontium unit fractional ratio of 0.88 was observed, with a standard deviation of 0.29.

Strontium unit ratios were then calculated using individual PMN station monthly average milk concentrations.

PMN stations and ITDSN stations were selected so as to be comparable. The resultant fractional ratios [MTD $(SU)_P$] were calculated using equation (5).

$$\text{MTD } (SU)_P = \frac{Sr_m \text{ (PMN)} \cdot Ca_d}{Ca_m \text{ (PMN)} \cdot Sr_d} \qquad (5)$$

where

Ca_m (PMN) = average calcium concentration in milk (g/kg), monthly average PMN station value.

On the basis of 641 monthly values a mean fractional ratio of 0.90 was observed with a standard deviation of 0.26.

The MTD (SU) ratios, using both ITDSN and PMN milk concentrations and ITDSN total diets results, are summarized in table 2. Comparison of results of the two methods of calculation on the basis of a "Z" test indicates that the two distributions are statistically the same at the 5 percent level of significance, where:

$$Z = \frac{\text{MTD } (SU)_P - \text{MTD } (SU)_I}{\sqrt{\frac{\sigma_I^2}{\eta_I} + \frac{\sigma_P^2}{\eta_P}}} \qquad (6)$$

$$Z = 0.76 < Z(0.05) = 1.64$$

This suggests that the approach based upon the strontium unit is the optimum approach upon which to base estimates.

Table 2. Ratio of milk and total diet strontium-90-to-calcium values

	MTD $(SU)_I$	MTD $(SU)_P$
Number of samples (n)	143	641
Mean	0.88	0.90
Standard deviation (σ)	0.29	0.26
90-percent confidence interval ($\pm 1.64\sigma$)	0.42 to 1.36	0.47 to 1.32

Estimates and evaluations

The strontium unit ratio approach based

upon PMN milk results indicates a mean ratio [MTD $(SU)_P$] of 0.90 for the period of January 1963 through December 1964. Using this 2-year mean ratio, estimates of ITDSN strontium–90 intakes for the conterminous United States were made as follows:

$$Sr_d = \frac{\overline{Ca_d} \quad \cdot \overline{SU}\ (PMN)}{\overline{MTD}\ (SU)_P} \qquad (7)$$

where

Sr_d = estimated average ITDSN strontium–90 intake (pCi/day),

$\overline{Ca_d}$ = monthly average ITDSN calcium intake (g/day),

$\overline{SU}$ (PMN) = PMN monthly average strontium–90-to-calcium ratio (pCi/g),

and

$\overline{MTD}\ (SU)_P$ = average milk to total diet strontium–90-to-calcium ratio

$= [(pCi/g)_{PMN}/(pCi/g)_{ITDSN}]$

$= 0.90.$

Estimates were made of monthly average ITDSN strontium–90 intakes, Sr_d, based on PMN strontium–90 concentrations in milk for the period January through June 1965. Estimates based upon a 1963 through 1964 mean milk to total diet strontium unit ratio of 0.90 were observed to be uniformly less than the observed monthly average ITDSN strontium–90 intakes by 20 to 25 percent. When comparison was made between 1963 and 1964 ratio values, the 1964 strontium unit ratio was observed to be below the 2-year value. This suggests that, relative to the total diet, the importance of milk as a dietary source of strontium–90 had decreased between 1963 and 1964. This trend is in agreement with the results observed for cesium–137 (*9*), and required consideration in applying MTD ratios.

Using the 1964 mean ratio of 0.77 [MTD $(SU)_P$], estimates of ITDSN monthly average strontium–90 intake were made for January through June 1965 (table 3), using PMN milk concentrations. The estimated strontium–90 intakes were uniformly within 10 percent of the ITDSN observed intakes. The ability of this approach to estimate monthly average strontium–90 intakes based upon the previous year's milk-to-total-diet ratio was thus demonstrated.

Table 3. Estimated and observed ITDSN monthly average strontium-90 intakes, January–June 1965

Month	Observed strontium-90 milk concentrations [a] (pCi/g)	Observed calcium intake [b] (g/day)	Estimated strontium-90 intake [c]		Observed average strontium-90 intake (pCi/day)
			0.90 [d] (pCi/day)	0.77 [e] (pCi/day)	
January	16.1	1.2	22	28	28
February	16.8	1.3	24	32	32
March	16.8	1.3	24	30	30
April	17.8	1.3	26	30	28
May	17.6	1.3	26	28	31
June	17.1	1.2	23	27	27

[a] Monthly average PMN strontium unit ratio (SU_m)
[b] Monthly average ITDSN dietary intake of calcium (Ca_d)
[c] Mean $\overline{Sr_d}$ for month
[d] Mean $\overline{MTD}\ (SU)_P$ for 1963 through 1964 based upon PMN milk concentrations and ITDSN total diet values
[e] Mean $\overline{MTD}\ (SU)_P$ for 1964

An evaluation was also made of the ability of the approach to estimate monthly maximum intakes for the population group represented by the ITDSN. The 1964 mean milk to total diet strontium unit ratio of 0.77 was used to estimate maximum strontium–90 intakes (table 4). Maximum monthly PMN strontium–90 to calcium values and monthly average ITDSN calcium intakes were used. It was observed that, except for April 1965, estimated maximum intakes of strontium–90 were within 17 percent of observed maximum intakes. In the case of April 1965, the estimated maximum strontium–90 intake was 40-percent high. It is appropriate to note at this point that the approach presented herein was developed on a

Table 4. Estimated and observed ITDSN maximum monthly strontium-90 intakes, January–June 1965

Month	Observed maximum strontium-90 milk concentrations [a] (pCi/g)	Observed calcium intake [b] (g/day)	Estimated maximum strontium-90 intake [c] (pCi/day)	Observed maximum strontium-90 intake (pCi/day)
January	41.2	1.2	64	64
February	36.9	1.3	63	73
March	39.3	1.3	67	81
April	45.2	1.3	77	55
May	42.3	1.3	71	69
June	34.8	1.2	48	45

[a] Monthly maximum PMN strontium unit ratio [SU_{max} (PMN)]
[b] Monthly average ITDSN dietary intake of calcium (Ca_d)
[c] Based upon maximum monthly PMN milk concentrations $\overline{MTD}\ (SU)_P = 0.77$ for 1964

network basis. Application on an individual station basis was not intended.

Discussion

Using ITDSN milk and total diet intakes in conjunction with PMN monthly average milk concentrations, fractional intakes of strontium–90 due to milk were calculated for the period 1963 through 1964 for the conterminous United States. Comparison between distributions of strontium–90 milk-to-total-diet ratios [MTD (^{90}Sr)] based upon (1) ITDSN milk and (2) PMN milk concentrations showed that the two methods of calculation yielded statistically different distributions at the 5-percent level of significance.

However, when milk-to-total-diet strontium unit ratios were calculated using both methods (ITDSN and PMN milk results), the resultant distribution could be considered statistically equivalent at the 5-percent level of significance. The feasibility of using PMN milk results in conjunction with ITDSN total diet results on a network basis was thus demonstrated.

For the purpose of making average and maximum ITDSN strontium–90 intake estimates, the strontium-unit approach based upon PMN milk concentrations was selected. Due to an observed decrease in the relative importance of milk as a dietary source of strontium–90 between 1963 and 1964, the 1964 mean ratio [$MTD(SU)_P$] of 0.77 was used to estimate 1965 strontium–90 intakes for the population group represented by the ITDSN. The 1964 mean ratio corresponds to a total-diet-to-milk ratio [TDM(SU)] of 1.30 for the conterminous United States. This mean value, while slightly lower, is comparable to 1.2 as obtained by Kulp and Schulert *(3,4)* and by Michelson *(5)*, and further suggests a decrease in the relative importance of milk as a dietary source of strontium–90 since the period covered by these studies *(3–5)*.

At current strontium–90 intake levels, the method presented herein is applicable where actual intakes are unknown. Although the relative importance of milk as a dietary source of strontium–90 decreased between 1963 and 1964, the 1964 mean strontium unit ratio facilitated estimates of 1965 observed monthly intakes on an ITDSN basis. Application of results presented herein to other than the ITDSN on a national basis must take into consideration regional variations and the population group of concern. Current efforts are directed toward an expansion of the material presented herein in an effort to quantitatively define regional variations and time variations in the strontium unit ratio.

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Section I. Milk and Food

In the determination of the internal exposure to man from environmental radiation sources, primary interest centers on radionuclides in the diet. Efforts are being made by both Federal and State agencies to monitor the intake of various radionuclides in the total diet on a continuing basis. The total diet is the most direct measure of intake of radionuclides; however, since specific dietary data are not readily available, indicator foods may be used to estimate radionuclide intake. As fresh milk is consumed by a large segment of the U.S. population, contains most of the biologically significant radionuclides from nuclear test debris which appear in the diet, and is the major source of dietary intake of short-lived radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides. In the absence of specific dietary information, it is possible to approximate the total daily dietary intake of selected radionuclides as being equivalent to the intake represented by the consumption of 1 liter of milk. More direct estimates of dietary intake of radionuclides than those furnished by indicator foods can be obtained by analyses of the total diet or representative principal food items or groups combined with appropriate consumption data.

The Federal Radiation Council (FRC) has developed Radiation Protection Guides (RPG's) for controlling normal peacetime nuclear operations, assuming continuous exposure from intake by the population at large (*1–3*). The RPG's do not and cannot establish a line which is safe on one side and unsafe on the other; they provide an indication of when there is a need to initiate careful evaluation of exposure (*3*). Additional guidelines are provided by the FRC Protective Action Guides (*4*) and by the International Commission on Radiological Protection (*5,6*).

Data from selected national, international, and State milk and food surveillance activities are presented herein. An effort has been made to present a cross-section of routine sampling programs which may be considered of a continuing nature. Routine milk sampling has been defined as one or more samples collected per month.

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NATIONAL AND INTERNATIONAL MILK SURVEILLANCE

As part of continuing efforts to quantitatively monitor man's exposure to radionuclides, various national and international organizations routinely monitor radionuclide levels in milk. In addition to those programs reported below, *Radiological Health Data and Reports* coverage includes:

Program	Period reported	Last presented
Radiostrontium in milk, HASL	July–December 1965	June 1966

1. Pasteurized Milk Network October 1966

National Center for Radiological Health and National Center for Urban and Industrial Health, PHS

The Public Health Service's Pasteurized Milk Network (PMN), was designed to provide nationwide surveillance of radionuclide concentrations in milk through sampling from major milk production and consumption areas. The present network of 63 sampling stations (figure 1) provides data on milk in every State, the Canal Zone, and Puerto Rico. The most recent description of the sampling and analytical procedures employed by the PMN appeared in the December 1966 issue of *Radiological Health Data and Reports* (*1*).

The results for the third quarter of 1966 and October 1966 are presented in table 1. The average monthly radionuclide concentrations are based on results obtained from samples collected weekly. If radionuclide values were

Figure 1. Pasteurized Milk Network sampling stations

Table 1. Average concentrations of radionuclides in pasteurized milk for the third quarter 1966 and October 1966 [a]

Station location		Concentration (pCi/liter)							
		Strontium-89		Strontium-90		Iodine-131		Cesium-137	
		Third quarter	Oct 1966	Third quarter	Oct 1966	Third quarter	Oct 1966	Third quarter	Oct 1966
Ala:	Montgomery	<5	NA	12	10	0	0	20	15
Alaska:	Palmer	<5	<5	11	14	10	0	30	15
Ariz:	Phoenix	<5	<5	3	3	0	0	10	<5
Ark:	Little Rock	5	NA	24	23	0	0	25	20
Calif:	Sacramento	<5	<5	4	3	10	0	10	5
	San Francisco	<5	<5	4	3	0	0	15	5
C.Z:	Cristobal	<5	NA	4	5	0	0	15	25
Colo:	Denver	<5	<5	7	9	0	0	15	5
Conn:	Hartford	<5	<5	11	11	0	0	30	20
Del:	Wilmington	<5	NA	12	12	0	0	20	20
D.C:	Washington	<5	NA	11	11	0	0	15	15
Fla:	Tampa	<5	NA	10	10	0	0	135	120
Ga:	Atlanta	5	NA	19	19	0	0	35	25
Hawaii:	Honolulu	<5	<5	4	3	0	0	20	15
Idaho:	Idaho Falls	<5	<5	10	11	0	0	20	15
Ill:	Chicago	<5	<5	8	8	0	0	20	15
Ind:	Indianapolis	<5	NA	10	9	0	0	15	15
Iowa:	Des Moines	<5	<5	12	8	0	0	20	15
Kans:	Wichita	<5	<5	11	13	0	0	10	10
Ky:	Louisville	<5	NA	16	13	0	0	10	10
La:	New Orleans	<5	<5	32	27	0	0	55	40
Maine:	Portland	<5	NA	14	15	0	0	50	45
Md:	Baltimore	<5	NA	12	12	0	0	20	15
Mass:	Boston	<5	<5	15	13	0	0	45	30
Mich:	Detroit	<5	<5	9	8	0	0	20	15
	Grand Rapids	<5	NA	12	11	0	0	25	20
Minn:	Minneapolis	<5	<5	17	21	0	0	25	10
Miss:	Jackson	<5	NA	20	19	0	0	25	20
Mo:	Kansas	<5	<5	13	13	0	0	10	10
	St. Louis	5	<5	15	15	0	0	20	15
Mont:	Helena	<5	<5	10	11	0	0	25	25
Nebr:	Omaha	<5	<5	11	11	0	0	15	10
Nev:	Las Vegas	<5	<5	4	4	0	0	10	5
N.H:	Manchester	<5	NA	18	14	0	0	75	45
N.J:	Trenton	<5	NA	11	10	0	0	20	20
N. Mex:	Albuquerque	<5	<5	7	4	0	0	10	10
N.Y:	Buffalo	<5	<5	10	9	0	0	25	20
	New York City	<5	NA	14	11	0	0	30	25
	Syracuse	<5	<5	10	9	0	0	25	20
N.C:	Charlotte	<5	NA	20	19	0	0	25	20
N. Dak:	Minot	<5	<5	21	26	0	0	25	20
Ohio:	Cincinnati	<5	NA	11	12	0	0	15	10
	Cleveland	<5	NA	11	10	0	0	20	15
Okla:	Oklahoma City	<5	5	12	11	0	0	10	10
Ore:	Portland	<5	<5	11	11	0	0	30	15
Pa:	Philadelphia	<5	<5	11	11	0	0	20	20
	Pittsburgh	<5	<5	15	12	0	0	25	20
P.R.:	San Juan	<5	NA	7	5	0	0	20	15
R.I:	Providence	<5	NA	15	13	0	0	35	25
S.C:	Charleston	<5	<5	20	22	0	0	50	35
S. Dak:	Rapid City	5	<5	14	20	0	0	15	15
Tenn:	Chattanooga	<5	NA	20	18	0	0	25	20
	Memphis	<5	NA	16	16	0	0	10	10
Tex:	Austin	<5	NA	5	3	0	0	10	5
	Dallas	<5	<5	11	11	0	0	10	10
Utah:	Salt Lake City	<5	<5	9	10	0	0	15	15
Vt:	Burlington	<5	NA	12	12	0	0	35	25
Va:	Norfolk	<5	NA	16	15	0	0	20	15
Wash:	Seattle	<5	<5	18	17	0	0	55	45
	Spokane	<5	<5	12	16	0	0	30	25
W. Va:	Charleston	<5	NA	14	14	0	0	15	10
Wis:	Milwaukee	<5	NA	8	9	0	0	20	15
Wyo:	Laramie	<5	<5	9	8	0	0	15	10
Network average		<5	<5	12.3	12.0	0	0	25	20

[a] Barium-140 concentrations were below detectable levels.
NA, no analysis.

below minimum detectable concentrations (*1*), averages were calculated using one-half the minimum detectable value; however, for iodine–131 and barium–140, zero was used for averaging purposes when concentrations were below minimum detectable levels.

For comparative purposes, distributions of strontium–90 and cesium–137 are presented in tables 2 and 3 for October 1965 and May through October 1966. The average strontium–90 concentrations in pasteurized milk from selected cities are presented in figure 2.

Table 2. Frequency distribution, Strontium-90 concentrations in milk at Pasteurized Milk Network stations October 1965 and May–October 1966

Strontium-90 (pCi/liter)	Number of stations						
	1965	1966					
	Oct.	May	June	July	Aug.	Sept.	Oct.
Under–10	8	10	9	14	15	21	18
10–19	46	38	41	39	40	37	39
20–29	7	12	10	9	7	5	6
30–39	2	3	3	1	1	0	0

Table 3. Frequency distribution, cesium-137 concentrations in milk at Pasteurized Milk Network stations October 1965 and May–October 1966

Cesium-137 (pCi/liter)	Number of stations						
	1965	1966					
	Oct.	May	June	July	Aug.	Sept.	Oct.
Under–50	54	51	56	56	56	61	62
50–99	8	11	6	6	6	1	0
100–149	0	1	1	1	1	1	1
150–199	1	0	0	0	0	0	0

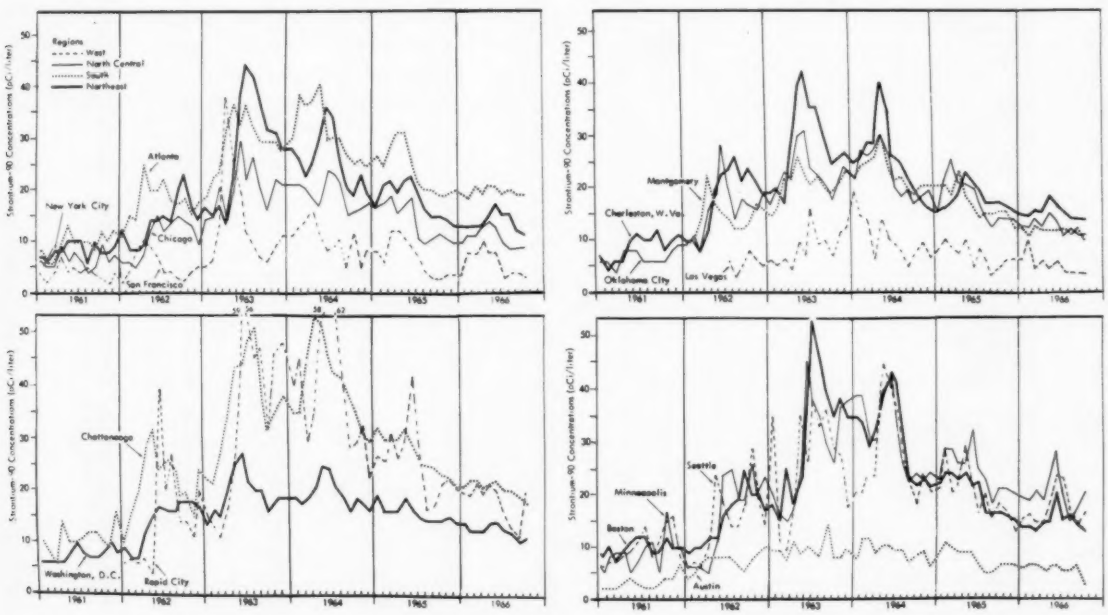

Figure 2. Strontium–90 concentrations in pasteurized milk, 1961–October 1966

2. Canadian Milk Network October 1966 [1]

Radiation Protection Division
Department of National Health and Welfare

Since November 1955, the Radiation Protection Division of the Department of National Health and Welfare has been monitoring milk for radionuclide concentrations. Powdered milk was originally sampled, but liquid whole milk has been sampled since January 1963. At present, 16 milk sampling stations (figure 3) are in operation. Their locations coincide with air and precipitation sampling stations.

Milk samples are collected three times a week from selected dairies and are combined into weekly composites. The contribution of each dairy to the composite sample is directly proportional to the liquid volume of sales. Weekly spot check analyses are made for iodine–131, and monthly composites are analyzed for strontium–90, cesium–137, and stable calcium and potassium. The analytical procedures were outlined in the December issue of *Radiological Health Data and Reports* (*2*).

The October 1966 monthly average strontium–90, cesium–137, and stable calcium and potassium concentrations in Canadian whole milk are presented in table 4. Iodine–131 and strontium–89 concentrations were below minimum detectable levels.

[1] Prepared from November 1966 monthly report "Data from Radiation Protection Programs," Canadian Department of National Health and Welfare, Ottawa, Canada.

Table 4. Stable elements and radionuclides in Canadian whole milk, October 1966

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Cesium-137 (pCi/liter)
Calgary	1.14	1.4	13.5	29
Edmonton	1.13	1.4	11.6	33
Ft. William	1.12	1.5	17.5	38
Fredericton	1.16	1.4	19.9	48
Halifax	1.13	1.4	17.8	42
Montreal	1.09	1.4	12.6	27
Ottawa	1.17	1.4	9.4	21
Quebec	1.11	1.5	21.2	48
Regina	1.12	1.5	11.2	27
St. John's, Nfld	1.08	1.4	27.3	69
Saskatoon	1.15	1.4	11.2	28
Sault Ste. Marie	1.10	1.5	16.8	42
Toronto	1.11	1.5	6.9	23
Vancouver	1.18	1.4	19.4	77
Windsor	1.12	1.4	7.0	14
Winnipeg	1.10	1.5	10.1	32
Average	1.13	1.4	14.6	37

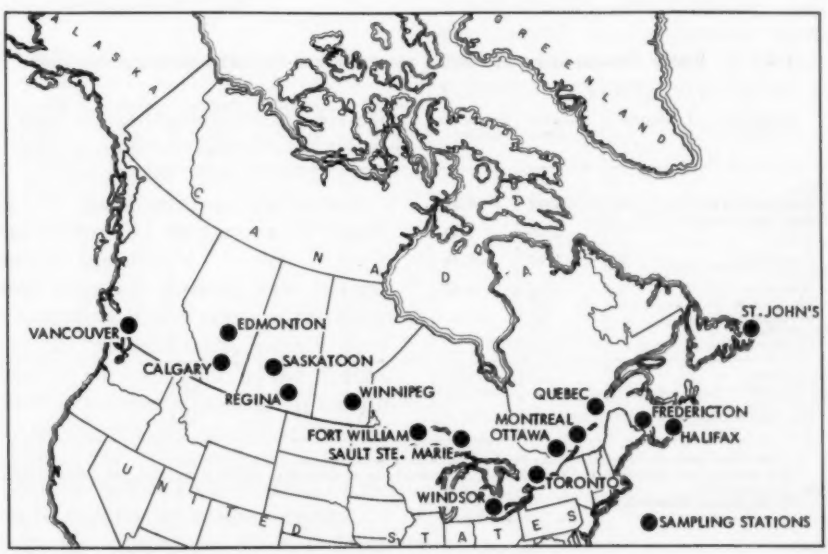

Figure 3. Canadian milk sampling stations

3. Pan American Milk Sampling Program October 1966

Pan American Health Organization and U.S. Public Health Service

The Pan American Health Organization (PAHO), in collaboration with the U.S. Public Health Service (PHS), furnishes assistance to health agencies in the American Republics in developing national radiological health programs.

Under a joint agreement between both agencies, air and milk sampling activities are conducted by a number of PAHO member countries (figure 4). Results of the milk sampling program are presented below. Further information on the sampling and analytical procedures employed was presented in the December 1966 issue of *Radiological Health Data and Reports* (*3*).

Table 5 presents stable calcium and potassium, strontium–89, strontium–90, and cesium–137 monthly average concentrations for October 1966.

Figure 4. Pan American Milk Sampling Program stations

Table 5. Stable element and radionuclide concentrations in PAHO milk, October 1966

Sampling station	Samples	Calcium (g/liter)	Potassium (g/liter)	Strontium-90 (pCi/liter)	Strontium-89 (pCi/liter) [a]	Cesium-137 (pCi/liter)	Iodine-131 [a] (pCi/liter)	Barium-140 [a] (pCi/liter)
Chile:								
Santiago	4	1.12	1.63	3	8	10	70	23
Colombia:								
Bogota	4	1.10	1.41	3	5	9	<10	<10
Ecuador:								
Guayaquil	3	1.10	1.59	2	38	7	63	43
Jamaica:								
Kingston	1	1.09	1.50	7	<5	135	<10	<10
Mandeville		NS						
Montego Bay		NS						
Venezuela:								
Caracas		NS						
Canal zone:								
Cristobal [b]				5		25		
Puerto Rico:								
San Juan [b]				5		15		

[a] Data have been corrected for decay to the date of sample collection.
[b] For comparison purposes, the radionuclide concentrations at Cristobal, Canal Zone, and San Juan, Puerto Rico, are presented.
NS, no sample collected.

REFERENCES

(*1*) PUBLIC HEALTH SERVICE. Pasteurized Milk Network, August 1966. Radiol Health Data Rep 7: 698–701 (December 1966).
(*2*) DEPARTMENT OF NATIONAL HEALTH AND WELFARE, RADIATION PROTECTION DIVISION. Canadian milk network, August 1966. Radiol Health Data Rep 7:702–703 (December 1966).
(*3*) PAN AMERICAN HEALTH ORGANIZATION and U.S. PUBLIC HEALTH SERVICE. Pan American Milk Sampling Program, August 1966. Radiol Health Data Rep 7:704 (December 1966).

STATE MILK SURVEILLANCE ACTIVITIES

Considerable progress has been made by the State health departments in initiating or expanding environmental surveillance activities in radiological health. Many of the States have reached a point of having comprehensive environmental surveillance programs and self-sustaining radiological health laboratories.

The continuing efforts of State health departments in the analysis and monitoring of radionuclides in milk complement Federal milk surveillance activities. State milk surveillance activities are continually undergoing developmental changes at this time. The results presented herein are representative of current surveillance activities directed at the use of milk as an indicator of dietary intake of radioactivity.

In addition to the State milk networks presented herein, programs previously covered in *Radiological Health Data and Reports* include:

State milk network	Period reported	Last presented
California	April–June 1966	December 1966
Colorado	January 1965–June 1966	October 1966
Florida	July–September 1966	January 1966
Oklahoma	July–September 1966	January 1966
Oregon	April–June 1966	December 1966
Texas	July–September 1966	January 1966
Washington	April–June 1966	December 1966

1. Connecticut Milk Network July–September 1966

Connecticut State Department of Health

The Connecticut State Department of Health has been monitoring pasteurized milk for strontium–89 and strontium–90 since April 1960. In May 1962, the program was expanded to include the determination of gamma-ray emitting radionuclides in milk.

The sampling program is flexible in nature, providing for sampling in five areas of the State (figure 1). At the present time, weekly samples representative of milk sold in the central area of the State are collected and analyzed for strontium–89, strontium–90, and gamma-ray-emitting radionuclides. Concentrations of iodine–131 are determined as an indication of the presence of radioactivity of recent origin.

Strontium–89 and strontium–90 are determined by chemical separation. Iodine–131 and other gamma-ray-emitting radionuclides are determined by gamma-ray-scintillation spectrometry.

The monthly average concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 in Connecticut pasteurized milk are presented in table 1. These results are presented graphically in figure 2.

Table 1. Radionuclide concentrations in central Connecticut milk, July–September 1966

Month	Radionuclide concentration (pCi/liter)			
	Strontium-89	Strontium-90	Iodine-131	Cesium-137
July	3	12	<10	30
August	<1	9	<10	30
September	<1	10	<10	20

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
April 1960–December 1962	May 1963
Annual summary 1963	September 1964
Annual summary 1964	May 1965
Annual summary 1965	May 1966
January–March 1966	August 1966
April–June 1966	November 1966

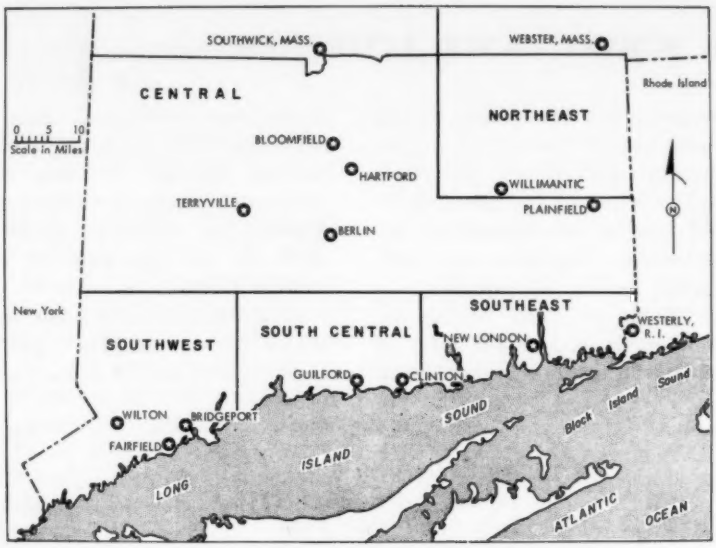

Figure 1. Connecticut pasteurized milk sampling areas

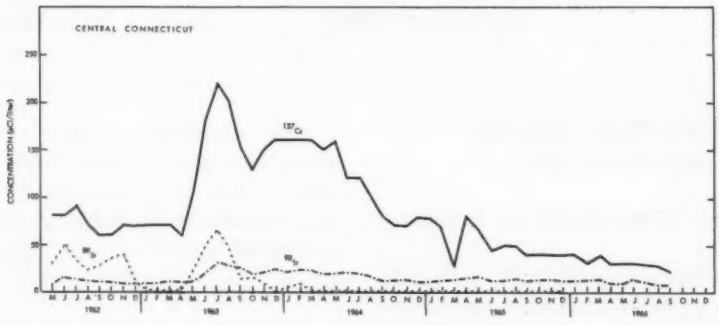
CENTRAL CONNECTICUT
CONCENTRATION (pCi/liter)
250
200
150
100
50
0
^{137}Cs
^{89}Sr
^{90}Sr
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966

Figure 2. Radionuclide concentrations in Connecticut pasteurized milk 1962–September 1966

2. Indiana Milk Network July–September 1966

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radionuclide analysis in September 1961. For sampling purposes, the State was geographically divided into five major milksheds: northeast, northwest, central, southeast, and southwest (figure 3). One large dairy within each milkshed was assumed to be representative for sampling purposes.

The milk samples are analyzed monthly for strontium–89 and strontium–90. Iodine–131, cesium–137, and barium–140 are analyzed weekly in at least two of the milksheds. When iodine–131 concentrations exceed 100 pCi/liter, the sampling frequency is increased. From August 1963 to April 1966, because of the continued low concentrations of short-lived radionuclides, the sampling frequency was once a month for the northeast, southeast, and southwest milksheds.

Strontium–89 and strontium–90 concentrations in milk samples are determined by ion exchange separation (*1,2*) while iodine–131,

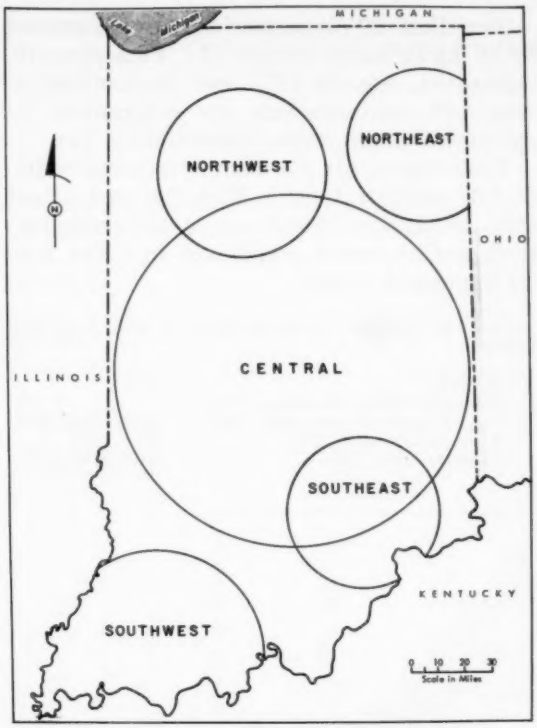

Figure 3. Indiana pasteurized milk sampling areas

cesium–137, and barium–140 are determined by gamma-ray-scintillation spectrometry (*3*).

The monthly radionuclide concentrations in Indiana pasteurized milk are presented by station in table 2 for July through September 1966, and reflect the mainland China atmospheric nuclear test of May 9, 1966.

Table 2. Radionuclides in Indiana milk, July–September 1966 [a]

Element and month	Sampling location					
	Northeast	Southeast	Central	Southwest	Northwest	Average
Calcium, g/liter						
July	1.18	1.21	1.20	1.17	1.18	1.19
August	1.09	1.13	1.11	1.16	1.11	1.12
September	1.43	1.32	1.35	1.38	1.35	1.37
Potassium-40, pCi/liter						
July	1,340	1,410	1,330	1,330	1,370	1,360
August	1,280	1,390	1,280	1,280	1,320	1,310
September	1,350	1,340	1,350	1,350	1,360	1,350
Strontium-89, pCi/liter						
July	5	10	10	10	15	10
August	0	5	5	0	5	5
September	0	0	0	0	0	0
Strontium-90, pCi/liter						
July	12	18	10	18	16	15
August	9	16	11	20	11	13
September	9	16	10	16	12	13
Cesium-137, pCi/liter						
July	25	25	20	20	30	25
August	20	25	15	20	30	20
September	20	15	10	15	15	15

[a] Iodine-131 and barium-140 concentrations were below detectable levels of 10 pCi/liter.

The monthly network average concentrations of strontium–89, strontium–90, and cesium–137 are presented graphically in figure 4. Iodine–131 and barium–140 concentrations remained below detectable levels of 10 pCi/liter during this period.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Annual summary 1961–1964	May 1965
Annual summary 1965	May 1966
January–March 1966	August 1966
April–June 1966	November 1966

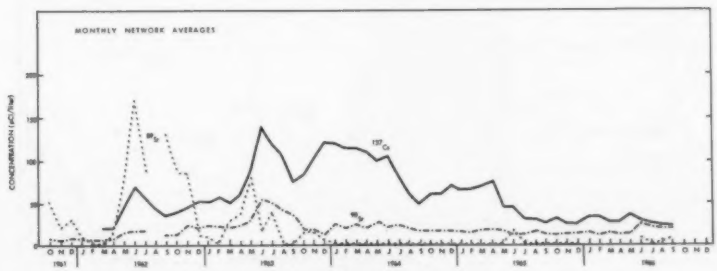
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
^{89}Sr
^{137}Cs
^{90}Sr
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1961
1962
1963
1964
1965
1966

Figure 4. Radionuclide concentrations in Indiana pasteurized milk 1961–September 1966

3. Michigan Milk Network July–September 1966

Division of Occupational Health
Michigan Department of Health

The Michigan Department of Health began sampling pasteurized milk for radionuclide analyses in November 1962. Under this program, weekly pasteurized milk samples are collected in the seven major milk-producing areas in the State: Charlevoix, Detroit, Grand Rapids, Lansing, Marquette, Monroe, and Saginaw (figure 5). Milkshed samples are composite samples of individual dairies in proportion to the volume of sales.

Strontium–90 concentrations are determined by an ion exchange method (*4*). Potassium–40, iodine–131, cesium–137, and barium-lanthanum–140 concentrations are determined by gamma-ray-scintillation spectrometry (*4*).

Table 3 presents the monthly average radionuclide concentrations in Michigan pasteurized milk. Strontium–90 and cesium–137 concentrations are presented graphically in figure 6 to show general trends.

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
November 1962–December 1964 and annual summary 1964	September 1965
Annual summary 1965	May 1966
January–June 1966	November 1966

Figure 5. Michigan pasteurized milk network sampling locations

Table 3. Radionuclide concentration in Michigan pasteurized milk, July–September 1966

Sampling location	Radionuclide concentrations (pCi/liter)											
	Potassium-40			Strontium-90			Iodine-131			Cesium-137		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Charlevoix	1,380	1,350	1,370	8	7	NA	<14	<14	<14	26	21	16
Detroit	1,320	1,310	1,330	4	4	NA	<14	<14	<14	18	16	11
Grand Rapids	1,320	1,300	1,350	9	6	NA	<14	<14	<14	26	21	18
Lansing	1,340	1,350	1,340	6	4	NA	<14	<14	<14	17	16	12
Marquette	1,320	1,290	1,330	17	11	NA	<14	<14	<14	75	51	35
Monroe	1,360	1,300	1,340	7	7	NA	<14	<14	<14	19	15	11
Saginaw	1,320	1,340	1,310	5	4	NA	<14	<14	<14	19	17	12
Average	1,340	1,320	1,340	8	6	NA	<14	<14	<14	29	22	16

NA, no analysis.

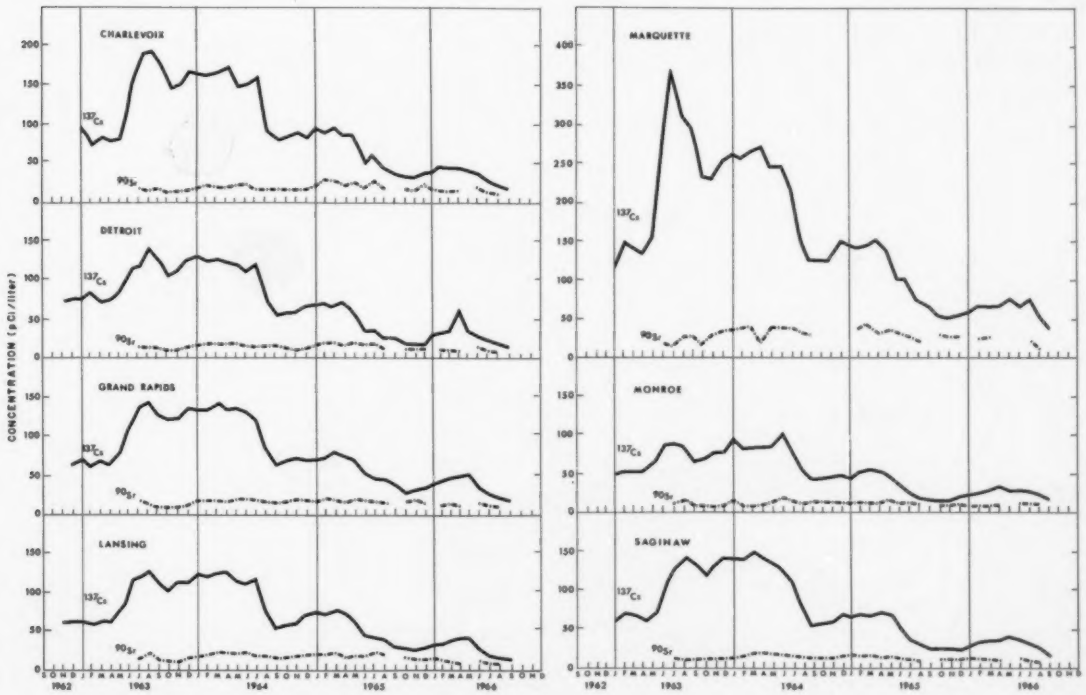

Figure 6. Radionuclide concentrations in Michigan pasteurized milk, 1962–September 1966

4. Minnesota Milk Network July–September 1966

Division of Environmental Health
Minnesota Department of Health

In September 1958, the Minnesota Department of Health initiated a pasteurized milk network to monitor strontium–90 concentrations. Presently, monthly samples are collected from eight sampling locations in milksheds which are geographically the same as the Minnesota health districts (figure 7). One-liter samples of processed Grade A fluid milk are collected at bottling machines in pasteurization plants. The samples are customarily collected in the cities where the Minnesota Health Department district offices are located. However, it is sometimes convenient to collect at other locations. Such samples are considered representative of the district concerned. Analyses are performed for strontium–90, iodine–131, and cesium–137 concentrations.

Strontium–90 concentrations are determined after radiochemical separation, while iodine–131 and cesium–137 concentrations are determined by gamma-ray-scintillation spectrometry. The analytical procedures are presented in the semiannual report of the Minnesota Department of Health and Rural Cooperative Power Association *(5)*.

Strontium–90 and cesium–137 concentrations in milk are given for July through September 1966 in table 4, and are presented graphically by milkshed in figure 8 for the period July through September 1966. Iodine–131 concentrations in milk were below 10 pCi/liter for this period and are omitted from table 4.

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
November 1962–December 1964	September 1965
Annual summary 1965	May 1966
January–March 1966	August 1966
April–June 1966	November 1966

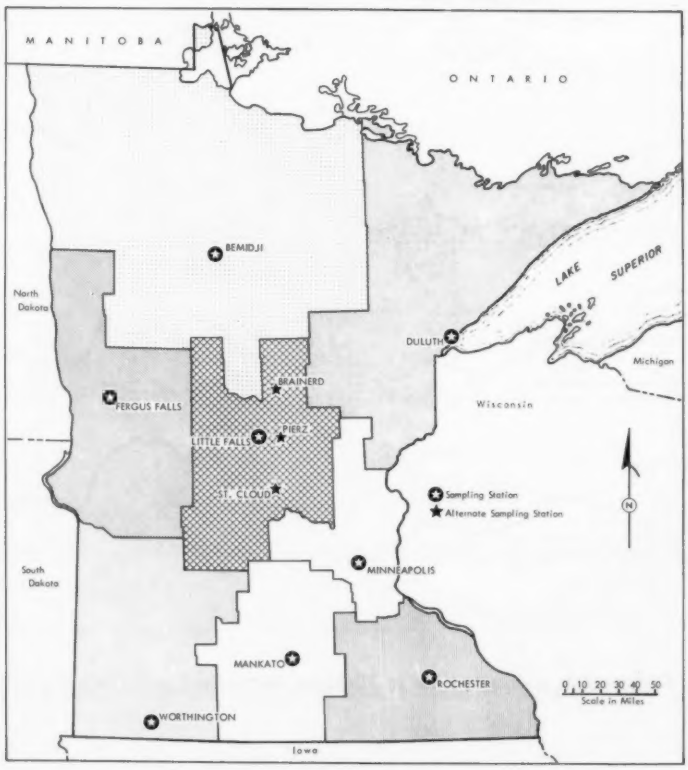

Figure 7. Minnesota milk sampling locations

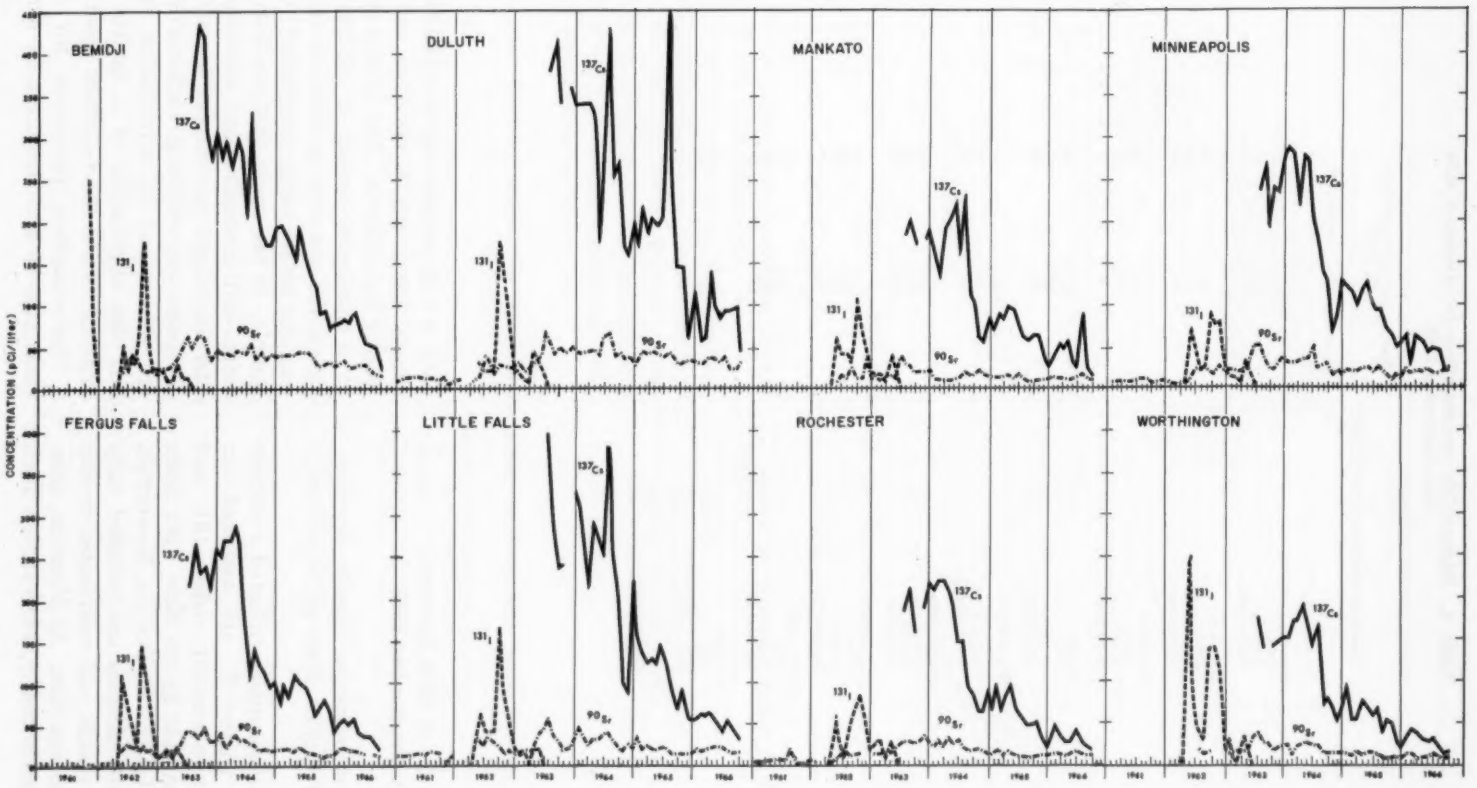

Figure 8. Radionuclide concentrations in Minnesota milk, 1961–September 1966

Table 4. Radionuclide concentrations in Minnesota milk July–September 1966

Sampling location and month 1966	Radionuclide concentrations (pCi/liter)	
	Strontium-90	Cesium-137
Bemidji		
July	21	63
August	16	52
September	15	22
Mankato		
July	16	89
August	12	23
September	10	13
Rochester		
July	12	24
August	8	19
September	9	15
Duluth		
July	21	88
August	22	97
September	26	42
Worthington		
July	12	27
August	8	13
September	10	18
Minneapolis		
July	11	45
August	13	22
September	14	22
Fergus Falls		
July	NA	30
August	13	26
September	11	18
Little Falls		
July	18	59
August	15	40
September	17	29
Average		
July	16	53
August	13	22
September	14	22

NA, no analysis.

5. New York Milk Network July–September 1966

Division of Environmental Health Services
Department of Health, State of New York

Pasteurized milk samples collected routinely from six cities (figure 9) are analyzed for strontium–89, strontium–90, iodine–131, and barium-lanthanum–140 by the New York State Department of Health. At Buffalo, Newburgh, and Syracuse, milk samples are collected daily from processing plants, and composited weekly for radiochemical analysis. At Massena, samples are composited biweekly, while at New York City, a milk sample representing the total milk supply for 1 day is obtained and composited weekly for analysis. The Albany sample, taken at a marketing point, is analyzed daily for iodine–131 and other gamma-ray-emitting radionuclides before being composited into a weekly sample. In the event that any sample contains iodine–131 concentrations exceeding 100 pCi/liter, increased surveillance is undertaken.

Gamma-ray-emitting radionuclides in milk are determined by scintillation spectrometry and the application of a matrix method of analysis (*6*) to the resultant spectral data.

The analytical procedure for determining strontium–89 and strontium–90 concentrations

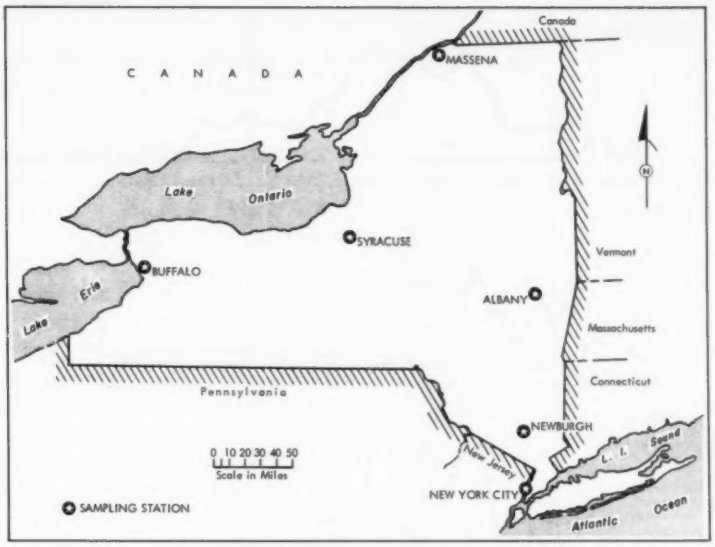

Figure 9. New York milk sampling stations

employs an ion exchange system similar to that developed by Porter and Kahn (*2*).

• The monthly average radionuclide concentrations of strontium–89, strontium–90, iodine–131, and cesium–137 are shown in table 5 for July through September 1966. Cesium–137 and iodine–131 concentrations since September 1961 are presented graphically in figure 10.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–September 1964	April 1965
October–December 1964	May 1965
Annual summary 1965	May 1966
January–June 1966	November 1966

Table 5. Radionuclide concentrations in New York milk, July–September 1966

Sampling locations	Radionuclide concentrations (pCi/liter)											
	Strontium-89			Strontium-90			Iodine-131			Cesium-137		
	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept	July	Aug	Sept
Albany	5	<3	<3	7	7	6	<20	<20	<20	<20	<20	<20
Ashford	4	NS	NA	15	NS	NA	<20	NS	<20	22	NS	<20
Bedford	NS	NS	NS	NS	NS	NS	<20	<20	<20	<20	<20	<20
Buffalo	<3	<3	<3	9	4	6	NS	NS	NS	NS	NS	NS
Clarktown	<3	<3	<3	6	6	7	<20	<20	<20	28	22	<20
East Otto	NA	NS	<3	NA	NS	9	<20	NS	<20	35	NS	<20
Massena	3	<3	NS	10	13	NS	<20	<20	NS	48	39	NS
Middleburg	4	<3	NA	10	9	NA	<20	<20	<20	29	<20	<20
Mount Pleasant	3	<3	<3	8	5	6	<20	<20	<20	26	<20	39
Newburgh	<3	<3	NA	10	14	NA	<20	<20	<20	21	<20	24
New York	NA	<3	<3	NA	10	11	<20	<20	<20	31	30	<20
Oyster Bay	NS	NA	<3	NS	NA	10	NS	<20	39	NS	47	27
Syracuse	NA	<3	<3	NA	<3	8	<20	<20	<20	<20	<20	<20
Yaphank	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Yorkshire	NA	NS	NA	NA	NS	NA	<20	NS	<20	22	NS	28
Yorktown	NA	NA	<3	NA	NA	20	<20	<20	<20	39	34	22
Average	3	<3	<3	9	8	9	<20	<20	<20	25	21	<20

NS, no sample
NA, no analysis

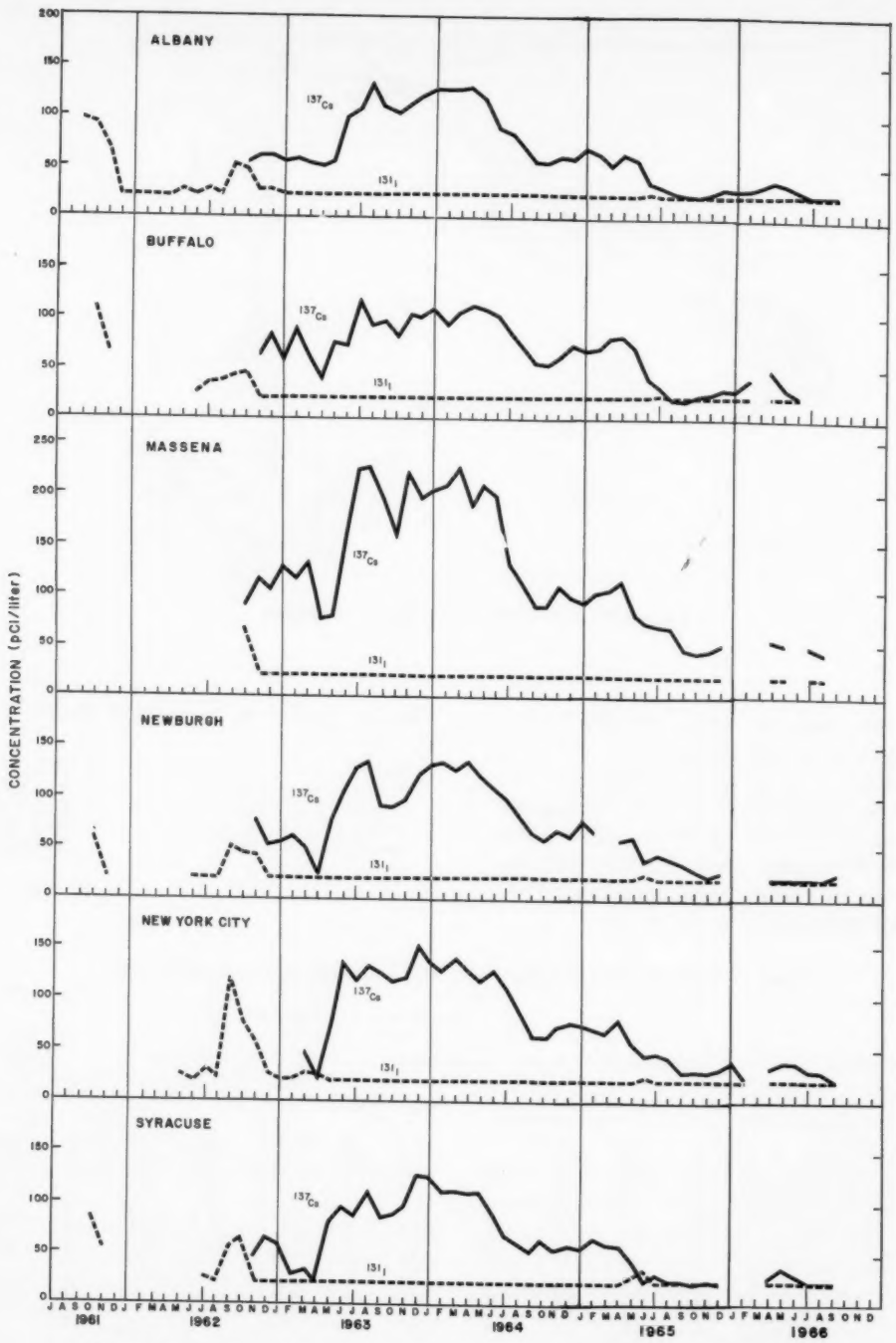
ALBANY
BUFFALO
MASSENA
NEWBURGH
NEW YORK CITY
SYRACUSE
^{137}Cs
^{131}I
CONCENTRATION (pCi/liter)
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1961
1962
1963
1964
1965
1966

Figure 10. Radionuclide concentrations in New York milk, 1961–September 1966

6. Pennsylvania Milk Network July–September 1966

Bureau of Environmental Health
Pennsylvania Department of Health

Samples of pasteurized milk are routinely collected from 10 major milk consumption areas throughout Pennsylvania (figure 11). Two samples per week are collected in Philadelphia and Pittsburgh, while weekly composite samples are collected from the other eight stations. At each sampling location sub-samples are collected from the major dairies supplying the area and are composited in proportion to the amount of milk processed by each dairy. This composite is then sent to the Radiation Laboratory of the Division of Occupational Health in Harrisburg where the weekly samples are combined for monthly analyses. Strontium–90 analyses have been carried out since April 1963.

The monthly average potassium–40, strontium–90, iodine–131, and cesium–137 concentrations in pasteurized milk are given in table 6. For comparative purposes, strontium–90, iodine–131, and cesium–137 concentrations are presented graphically in figure 12.

The chemical separation technique for strontium–90 is based on an ion exchange method described by Porter and Kahn (*2*).

Table 6. Radionuclide concentrations in Pennsylvania milk July–September 1966

Sampling location and month 1966	Radionuclide concentrations (pCi/liter)			
	Potassium-40	Strontium-90	Iodine-131	Cesium-137
Altoona				
July	886	9.0	<10	22.0
August	NA	15.0	NA	NA
September	NA	11.5	NA	NA
Dauphin				
July	798	15.0	<10	20.5
August	NA	15.0	NA	NA
September	NA	10.5	NA	NA
Erie				
July	862	20.5	11	32.0
August	835	15.5	14	33.0
September	NA	11.5	NA	NA
Kingston				
July	883	27.5	<10	38.0
August	802	21.0	ND	33.0
September	NA	16.0	NA	NA
Lancaster				
July	864	10.7	<10	25.0
August	800	11.5	10	20.0
September	NA	10.0	NA	NA
Philadelphia				
July	876	17.5	<10	22.5
August	849	13.0	10	21.0
September	NA	4.5	NA	NA
Pittsburgh				
July	848	24.0	<10	28.5
August	884	20.0	10	25.0
September	NA	15.0	NA	NA
Reading				
July	840	15.0	<10	19.0
August	NA	11.0	NA	NA
September	NA	4.5	NA	NA
Williamsport				
July	738	14.5	28.5	38.5
August	NA	16.5	NA	NA
September	NA	10.5	NA	NA
York				
July	859	9.5	<10	26.0
August	NA	13.0	NA	NA
September	NA	10.0	NA	NA
Average				
July	846	16.4	<10	27.2
August	834	15.2	<10	26.4
September	NA	11.4	NA	NA

NA, no analysis
ND, not detectable

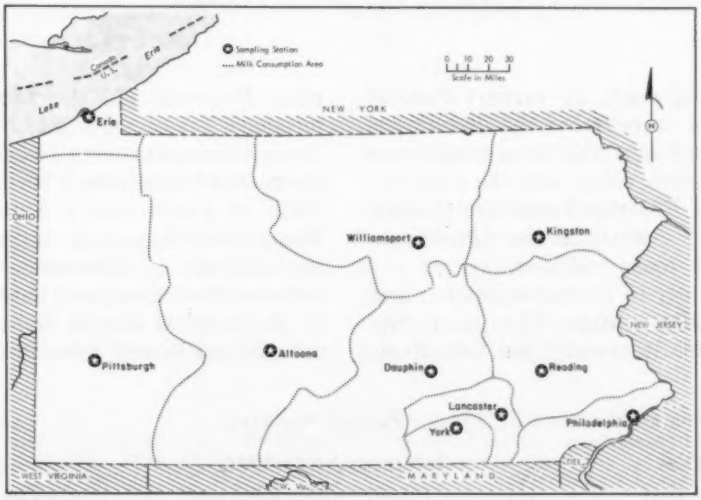

Figure 11. Pennsylvania pasteurized milk network sampling locations

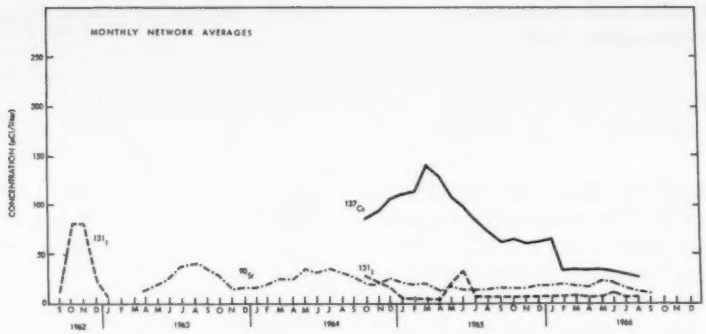
MONTHLY NETWORK AVERAGES
CONCENTRATION (pCi/liter)
250
200
150
100
50
0
^{137}Cs
^{131}I
^{90}Sr
^{131}I
S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1962
1963
1964
1965
1966

Figure 12. Radionuclide concentrations in Pennsylvania pasteurized milk 1962–September 1966

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
August–September 1964	February 1965
Annual summary 1964	June 1965
Annual summary 1965	May 1966
January–March 1966	August 1966
April–June 1966	November 1966

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(*3*) INDIANA STATE BOARD OF HEALTH, BUREAU OF ENVIRONMENTAL SANITATION. Indiana milk network, April-June 1965. Radiol Health Data 6:612–614 (November 1965).

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(6) KAHN, B., G. K. MURTHY, C. PORTER, G. R. HAGEE, G. J. KARCHES, and A. S. GOLDIN. Rapid methods for estimating fission product concentrations in milk, PHS Publication No. 999–R–2. Copies available on request from Public Inquiries Branch, PHS, U.S. Department of Health, Education, and Welfare, Washington, D.C. 20201 (March 1963).

FOOD AND DIET SURVEILLANCE ACTIVITIES

Efforts are being made by various Federal and State agencies to estimate the dietary intake of selected radionuclides on a continuous basis. These estimates, along with the guidance developed by the Federal Radiation Council provide a basis for evaluating the significance of radioactivity in foods and diet.

Networks presently in routine operation and reported periodically include: (1) the Public Health Service's Institutional Total Diet Sampling Network, (2) the Atomic Energy Commission's Tri-City Diet Study, (3) the Food and Drug Administration's Teenage Diet Study, (4) the State of California's Diet Study, and (5) the State of Connecticut's Standard Diet Study. These networks provide data useful for developing estimates of nationwide dietary intakes of radionuclides. Programs most recently reported in *Radiological Health Data and Reports* and not covered in this issue are listed below:

Program	Period reported	Last presented
California Diet	January–April 1966	January 1967
Connecticut Diet	January–June 1965	February 1966
Institutional Diet, PHS	April–June 1966	January 1967
Tri-City Diet, HASL	February–April 1966	December 1966
Teenage Diet, FDA	February–November 1965	August 1966

Section II. Water

The Public Health Service, the Federal Water Pollution Control Administration, and other federal, State, and local agencies operate extensive water quality sampling and analysis programs for surface, ground, and treated water. Most of these programs include determinations of gross beta and gross alpha radioactivity and of specific radionuclides.

Although the determination of the total radionuclide intake from all sources is of primary importance, a measure of the public health importance of radioactivity levels in water can be obtained by comparison of the observed values in treated water or dissolved solids fractions of raw surface water with the Public Health Service Drinking Water Standards (*1*). These Standards, based on consideration of Federal Radiation Council (FRC) recommendations *(2–4)*, set the upper limits for approval of a drinking water supply containing radium–226 and strontium–90 as 3 pCi/liter and 10 pCi/liter, respectively. Limits may be higher if total intake of radioactivity from all sources indicates that such intakes are within the guides recommended by FRC for control action. In the known absence[1] of strontium–90 and alpha emitters, the limit is 1,000 pCi/liter gross beta radioactivity, except when more complete analysis indicates that concentrations of radionuclides are not likely to cause exposures greater than the Radiation Protection Guides. Surveillance data from a number of federal and State programs are published periodically to show current and long-range trends. Water programs previously reported in *Radiological Health Data and Reports* are listed below.

[1] Absence is taken to mean a negligibly small fraction of the specific limits of 10 pCi/liter and 3 pCi/liter for strontium–90 and unidentified alpha-particles emitters, respectively.

Program	Period reported	Last presented
California Water Sampling Program	July–December 1965	November 1966
Coast Guard Water Sampling Program	1965	November 1966
Colorado River Basin Sampling Network	1962–1964	November 1965
Drinking Water Analysis Program	1962	October 1965
Florida Water Sampling Program	1964	November 1965
Kentucky Water Sampling Program	May 1963–June 1964	March 1965
Lower Columbia River Radiological Survey in Oregon	August 1963–July 1964	October 1965
Minnesota Surface Water Sampling Program	July–December 1965	July 1966
New York Surface Water Sampling Program	June–December 1965	June 1966
North Carolina Water Sampling Program	1964	November 1965
Radiostrontium in Tap Water, HASL	May and July–November 1965	June 1966
Washington Surface Water Sampling Program	July 1964–June 1965	May 1966

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GROSS RADIOACTIVITY IN SURFACE WATERS OF THE UNITED STATES, AUGUST 1966

Division of Pollution Surveillance
Federal Water Pollution Control Administration
Department of Interior

The monitoring of levels of radioactivity in surface waters of the United States was started in 1957 as a part of the Federal Water Pollution Control Administration's Water Pollution Surveillance System. Table 1 presents the current preliminary results of the alpha-particle and beta-particle analyses. The radioactivity associated with dissolved solids provides a rough indication of the levels that would occur in treated water, since nearly all suspended matter is removed by treatment processes. Strontium–90 results are reported quarterly. The stations on each river are arranged in the table according to their distance from the headwaters. Figure 1 indicates the average total beta radioactivity in suspended-plus-dissolved solids in raw water collected at each station. A description of the sampling and analytical procedures was published in the June 1966 issue of *Radiological Health Data and Reports.*

Complete data and exact sampling locations are published in annual compilations and are available on request (*1–6*).

Special note is made when the alpha radioactivity is 15 pCi/liter or greater or when the beta radioactivity is 150 pCi/liter or greater. These arbitrary levels provide a basis for the selection of certain data and for comment on the data, if needed. They reflect no public health significance as the Public Health Service drinking water standards have already provided the basis for this assessment. Changes from or toward these arbitrary levels are also noted in terms of changes in radioactivity per unit weight of solids. No discussion of gross radioactivity per gram of dissolved or sus-

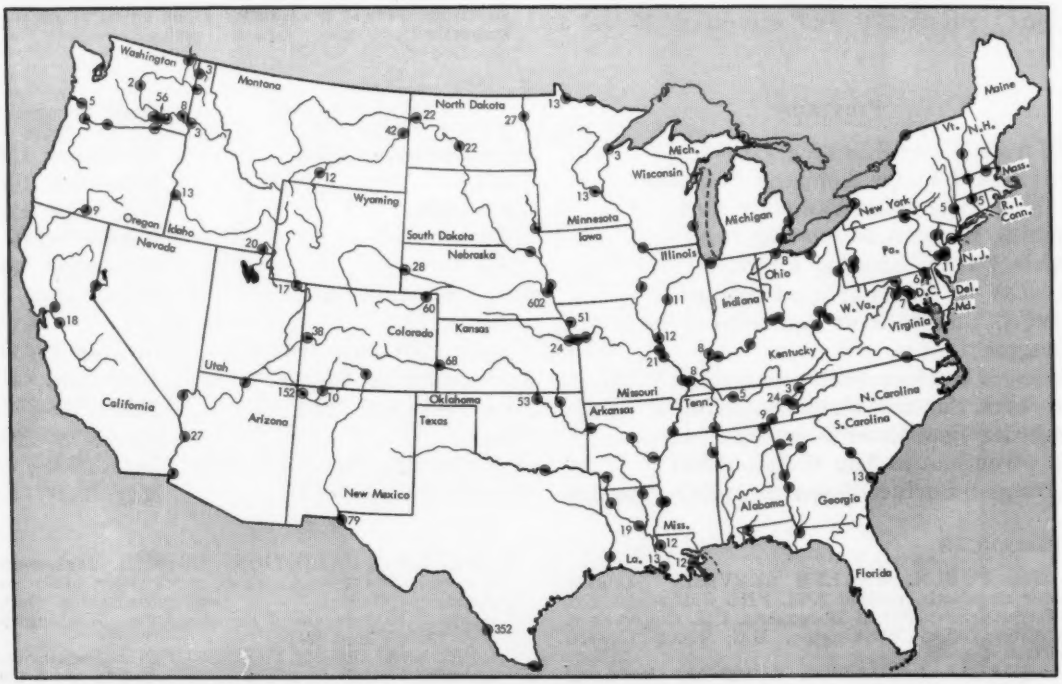

Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, August 1966

pended solids for all stations of the Water Pollution Surveillance System will be attempted. Comments are made only on monthly average values. Occasional high values from single weekly samples may be absorbed into a relatively low average. When these values are significantly high, comment will be made.

During both July and August the following stations showed alpha radioactivity in excess of 15 pCi/liter on either dissolved or suspended solids:

Arkansas River: Coolidge, Kans.
Rio Grande: Laredo, Tex.
South Platte River: Julesburg, Colo.

Shiprock, N. Mex., on the San Juan River, and Plattsmouth, Nebr., on the Platte River, showed increases of suspended alpha radioactivity in excess of 15 pCi/liter. Laredo, Tex., on the Rio Grande, showed beta radioactivity on suspended solids in excess of 150 pCi/liter. This was due entirely to high quantities of suspended solids.

On the Columbia River at Pasco, Wash., only the last sample of the month showed appreciable beta radioactivity in the dissolved solids. The Hanford reactors were not operating for most of this period.

Table 1. Radioactivity in raw surface waters, August 1966

Station	Average beta radioactivity (pCi/liter)			Average alpha radioactivity (pCi/liter)		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Animas River:						
Cedar Hill, N. Mex.	3	7	10	1	1	2
Arkansas River:						
Coolidge, Kans.	42	26	68	11	11	22
Ponca City, Okla.	41	12	53	14	0	14
Atchafalaya River:						
Morgan City, La.	3	10	13	<1	1	1
Bear River:						
Preston, Idaho	0	20	20	0	5	5
Big Horn River:						
Hardin, Mont.	3	9	12	0	3	3
Clearwater River:						
Lewiston, Idaho	1	2	3	0	0	0
Clinch River:						
Clinton, Tenn.	0	3	3	0	0	0
Kingston, Tenn.[a]	7	17	24	0	0	0
Colorado River:						
Loma, Colo.	20	18	38	3	7	10
Parker Dam, Calif-Ariz.	1	26	27	0	11	11
Columbia River:						
Wenatchee, Wash.	0	2	2	0	0	0
Pasco, Wash.[a]	5	51	56	0	0	0
Clatskanie, Ore.	0	5	5	0	1	1
Connecticut River:						
Enfield Dam, Conn.	1	4	5	0	0	0
Coosa River:						
Rome, Ga.	1	3	4	0	0	0
Cumberland River:						
Cheatham Lock, Tenn.	1	4	5	0	0	0
Delaware River:						
Philadelphia, Pa.	4	7	11	0	0	0
Great Lakes:						
Duluth, Minn.	0	3	3	0	0	0
Green River:						
Dutch John, Utah	1	16	17	0	3	3
Hudson River:						
Poughkeepsie, N.Y.	0	5	5	0	0	0
Illinois River:						
Peoria, Ill.	2	9	11	0	1	1
Grafton, Ill.	2	10	12	0	0	0
Kansas River:						
DeSoto, Kans.	6	18	24	3	2	5
Klamath River:						
Keno, Ore.	<1	9	9	0	0	0
Maumee River:						
Toledo, Ohio	0	8	8	0	0	0
Mississippi River:						
St. Paul, Minn.	1	12	13	0	0	0
E. St. Louis, Ill.	7	14	21	2	2	4
New Roads, La.	2	10	12	1	1	2
New Orleans, La.	1	11	12	0	1	1
Missouri River:						
Williston, N. Dak.	6	16	22	1	2	3
Bismarck, N. Dak.	7	15	22	2	3	5
St. Joseph, Mo.	35	16	51	11	3	14
North Platte River:						
Henry, Nebr.	5	23	28	<1	10	10
Ohio River:						
Cairo, Ill.	2	6	8	0	0	0
Pend Oreille River:						
Albeni Falls Dam, Idaho	<1	3	3	0	<1	<1
Platte River:						
Plattsmouth, Nebr.	106	14	120	20	1	21
Potomac River:						
Washington, D.C.	1	6	7	0	0	0
Rainy River:						
Baudette, Minn.	2	11	13	0	0	0
Red River, North:						
Grand Forks, N. Dak.	5	22	27	1	2	3
Red River, South:						
Alexandria, La.	3	16	19	0	0	0
Rio Grande:						
El Paso, Tex.	65	14	79	13	3	16
Laredo, Tex.	333	19	352	85	5	90
San Joaquin River:						
Vernalis, Calif.	9	9	18	2	5	7
San Juan River:						
Shiprock, N. Mex.	137	15	152	45	4	49
Savannah River:						
Port Wentworth, Ga.[a]	2	11	13	<1	2	2
Snake River:						
Payette, Idaho	1	12	13	<1	4	4
Wawawai, Wash.	1	7	8	0	1	1
South Platte River:						
Julesburg, Colo.	13	47	60	1	30	31
Susquehanna River:						
Conowingo, Md.	2	4	6	0	0	0
Tennessee River:						
Chattanooga, Tenn.	4	5	9	0	0	0
Wabash River:						
New Harmony, Ind.	1	7	8	0	1	1
Yellowstone River:						
Sidney, Mont.	25	17	42	5	3	8
Maximum	333	51	352	85	30	90
Minimum	0	2	2	0	0	0

[a] Gross beta radioactivity at this station may not be directly comparable to gross beta radioactivity at other stations because of the possible contribution of radionculides from an upstream nuclear facility in addition to the contribution from fallout and naturally occurring radionuclides common to all stations.

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(*1*) PUBLIC HEALTH SERVICE, DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. National water quality network annual compilation of data, PHS Publication No. 663, 1958 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(*2*) *Ibid.*, 1959 Edition.

(*3*) *Ibid*, 1960 Edition.

(*4*) *Ibid.*, 1961 Edition.

(*5*) *Ibid.*, 1962 Edition.

(*6*) PUBLIC HEALTH SERVICE. DIVISION OF WATER SUPPLY AND POLLUTION CONTROL. Water pollution surveillance system, annual compilation of data, PHS Publication No. 663 (Revised), 1963 Edition. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Section III. Air and Deposition

RADIOACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of radioactivity in air and precipitation provides one of the earliest indications of changes in environmental fission product activity. To date, this surveillance has been confined chiefly to the analysis of gross beta radioactivity. Although such data are insufficient to assess total human radiation exposure, they can be used to determine when to modify monitoring in other phases of the environment.

Surveillance data from a number of programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. These include data from activities of the U.S. Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization.

An intercomparison of the results from the above networks was performed by Lockhart and Patterson (*1*) in 1962. In addition to the programs presented in this issue, the following programs were previously covered in *Radiological Health Data and Reports.*

Network	Period	Issue
HASL Fallout Network	July–December 1965	September 1966
HASL 80th Meridian Network	Calendar year 1965	January 1967

1. Radiation Surveillance Network October 1966

National Center for Radiological Health
Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) which regularly gathers samples at 74 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

Daily samples of airborne particulates and precipitation are forwarded to the Radiation Surveillance Network Laboratory in Rockville, Maryland, for laboratory analysis. The alerting function of the network is provided by routine field estimates of the gross beta radioactivity made by the station operators prior to submission of the samples for laboratory analysis. When high radioactivity levels in air are reported, appropriate officials are promptly notified. Compilation of field estimates and laboratory confirmations are reported elsewhere on a monthly basis (*2*). A detailed description of the sampling and analytical procedures was presented in the November 1966 issue of *Radiological Health Data and Reports.*

Table 1 presents the monthly average gross beta radioactivity in surface air and deposition by precipitation during October 1966. Time profiles of gross beta radioactivity in air for eight RSN stations are shown in figure 2. Fresh fission products, at very low levels, were identified on the samples collected at Agana, Guam, on October 28 and 29, 1966. Gamma-ray analyses of the remaining 305 RSN air samples were negative.

Figure 1. Sampling locations and associated total beta activity (pCi/liter) in surface waters, August 1966

Table 1. Gross beta radioactivity in surface air and precipitation, October 1966

Station location		Number of samples		Air surveillance (gross beta radioactivity, pCi/m³)			Last profile in *RHD & R*	Precipitation	
		Air	Pptn	Maximum	Minimum	Average [a]		Total depth (mm)	Total gross beta radioactive deposition (nCi/m²)
Ala:	Montgomery	31	4	<0.10	<0.10	<0.10	Nov 66	126	<25
Alaska:	Adak	28		<0.10	<0.10	<0.10	June 66	[b]	
	Anchorage	19	3	<0.10	<0.10	<0.10	Dec 66	18	<4
	Attu Island	15		<0.10	<0.10	<0.10	July 66	[b]	
	Fairbanks	22	6	<0.10	<0.10	<0.10	Jan 67	7	<1
	Juneau	19	15	<0.10	<0.10	<0.10	Feb 67	294	<59
	Kodiak	2		<0.10	<0.10	<0.10	May 66	[b]	
	Nome	6		<0.10	<0.10	<0.10	Sept 66	[b]	
	Pt. Barrow	28		<0.10	<0.10	<0.10	Aug 66	[b]	
	St. Paul Island	20		<0.10	<0.10	<0.10	Oct 66	[b]	
Ariz:	Phoenix	26		0.17	<0.10	<0.10	Feb 67	[b]	
Ark:	Little Rock	31	6	<0.10	<0.10	<0.10	Dec 66	55	<11
Calif:	Berkeley	20		<0.10	<0.10	<0.10	May 66	[b]	
	Los Angeles	20	1	<0.10	<0.10	<0.10	Sept 66	2	<1
C.Z:	Ancon	16		<0.10	<0.10	<0.10	Feb 67	[b]	
Colo:	Denver	28	1	0.11	<0.10	<0.10	May 66	2	<1
Conn:	Hartford	30	7	<0.10	<0.10	<0.10	Jan 67	72	<15
Del:	Dover	21		<0.10	<0.10	<0.10	Nov 66	[b]	
D.C:	Washington	28	5	<0.10	<0.10	<0.10	Aug 66	96	<19
Fla:	Jacksonville	28	9	<0.10	<0.10	<0.10	Dec 66	107	<22
	Miami	27	7	<0.10	<0.10	<0.10	Jan 67	170	<34
Ga:	Atlanta	[c]	1				Oct 66	25	<5
Guam:	Agana	31		0.22	<0.10	<0.11	Nov 66	[b]	
Hawaii:	Honolulu	30	2	<0.10	<0.10	<0.10	July 66	58	<12
Idaho:	Boise	30	4	<0.10	<0.10	<0.10	July 66	32	<6
Ill:	Springfield	30	4	<0.10	<0.10	<0.10	Aug 66	58	<12
Ind:	Indianapolis	30	6	<0.10	<0.10	<0.10	Oct 66	54	<11
Iowa:	Iowa City	31	4	<0.10	<0.10	<0.10	Feb 67	57	<12
Kans:	Topeka	31	2	<0.10	<0.10	<0.10	Dec 66	7	<2
Ky:	Frankfort	31	3	<0.10	<0.10	<0.10	Aug 66	21	<4
La:	New Orleans	31	7	<0.10	<0.10	<0.10	Aug 66	99	<20
Maine:	Augusta	30	8	<0.10	<0.10	<0.10	Sept 66	130	<26
	Presque Isle	21	7	<0.10	<0.10	<0.10	Feb 67	58	<12
Md:	Baltimore	20	5	<0.10	<0.10	<0.10	Jan 67	44	<9
	Rockville	14		<0.10	<0.10	<0.10	July 66	[b]	
Mass:	Lawrence	31	5	<0.10	<0.10	<0.10	Nov 66	79	<16
	Winchester	31	5	<0.10	<0.10	<0.10	June 66	55	<11
Mich:	Lansing	30	6	<0.10	<0.10	<0.10	July 66	20	<4
Minn:	Minneapolis	20	4	<0.10	<0.10	<0.10	Nov 66	96	<19
Miss:	Jackson	31	3	<0.10	<0.10	<0.10	Sept 66	49	<10
Mo:	Jefferson City	30	7	<0.10	<0.10	<0.10	Oct 66	59	<12
Mont:	Helena	31	5	0.16	<0.10	<0.10	June 66	19	<4
Nebr:	Lincoln	19	1	0.31	<0.10	<0.11	Oct 66	1	<1
Nev:	Las Vegas	27		<0.10	<0.10	<0.10	Jan 67	[b]	
N.H:	Concord	18		<0.10	<0.10	<0.10	Aug 66	[b]	
N.J:	Trenton	31	4	<0.10	<0.10	<0.10	Sept 66	34	<7
N. Mex:	Sante Fe	29	2	<0.10	<0.10	<0.10	June 66	7	<2
N.Y:	Albany	19	6	<0.10	<0.10	<0.10	Oct 66	56	<11
	Buffalo	24		<0.10	<0.10	<0.10	Feb 67	[b]	
	New York	31		<0.10	<0.10	<0.10	June 66	[b]	
N.C:	Gastonia	31	7	<0.10	<0.10	<0.10	Feb 67	96	<19
N. Dak:	Bismarck	31	3	<0.10	<0.10	<0.10	Aug 66	19	<4
Ohio:	Cincinnati	20		<0.10	<0.10	<0.10	Nov 66	[b]	
	Columbus	29	4	<0.10	<0.10	<0.10	Sept 66	35	<7
	Painesville	29	6	<0.10	<0.10	<0.10	Jan 67	40	<8
Okla:	Oklahoma City	31	1	<0.10	<0.10	<0.10	July 66	1	<1
	Ponca City	31	2	<0.10	<0.10	<0.10	Jan 67	21	<4
Ore:	Portland	31	13	<0.10	<0.10	<0.10	Oct 66	67	<13
Pa:	Harrisburg	31	2	<0.10	<0.10	<0.10	Oct 66	53	<11
P.R:	San Juan	30	8	0.23	<0.10	<0.11	Sept 66	124	<25
R.I:	Providence	24	4	<0.10	<0.10	<0.10	July 66	82	<16
S.C:	Columbia	26	5	<0.10	<0.10	<0.10	June 66	66	<13
S. Dak:	Pierre	29	3	<0.10	<0.10	<0.10	Feb 67	16	<3
Tenn:	Nashville	31	6	<0.10	<0.10	<0.10	July 66	77	<16
Tex:	Austin	31	5	<0.10	<0.10	<0.10	Nov 66	29	<6
	El Paso	28		<0.10	<0.10	<0.10	Aug 66	[b]	
Utah:	Salt Lake City	31	3	<0.10	<0.10	<0.10	Sept 66	43	<9
Vt:	Barre	31	7	<0.10	<0.10	<0.10	Dec 66	44	<9
Va:	Richmond	30	6	<0.10	<0.10	<0.10	Dec 66	103	<21
Wash:	Seattle	31	11	<0.10	<0.10	<0.10	Dec 66	76	<15
	Spokane	28		<0.10	<0.10	<0.10	Nov 66	[b]	
W. Va:	Charleston	30	8	<0.10	<0.10	<0.10	June 66	38	<8
Wis:	Madison	31	3	<0.10	<0.10	<0.10	Dec 66	46	<9
Wyo:	Cheyenne	29	2	<0.10	<0.10	<0.10	Jan 67	4	<1
Network summary		1,931	274	0.31	<0.10	<0.10		57	<12

[a] The monthly average is calculated by weighting the individual sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes If 10 percent or more samples from a station contain <0.10 pCi/m³, a less-than sign is placed before the average.
[b] No precipitation sample collected.
[c] No report received.

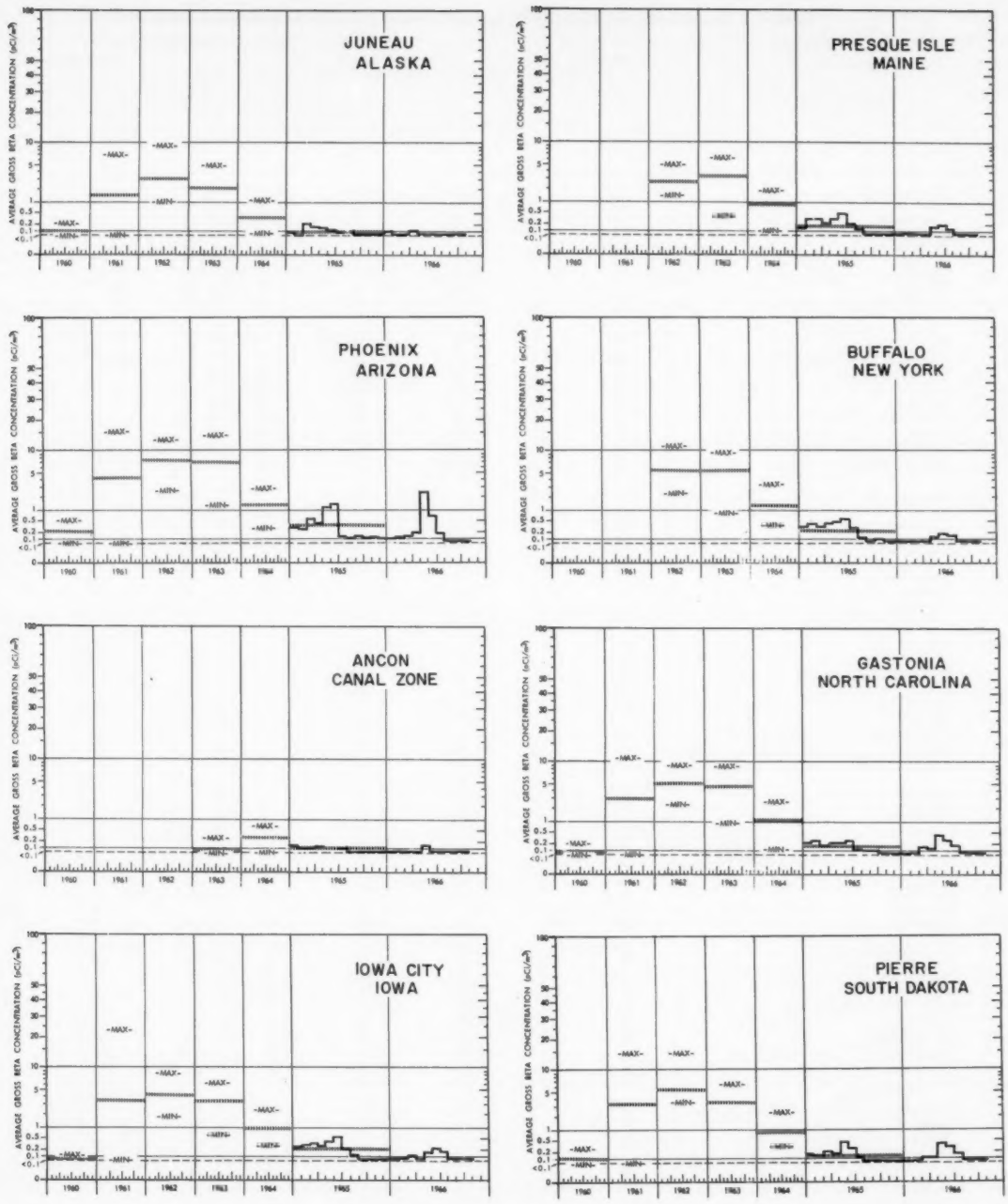

Figure 2. Monthly and yearly profiles of beta radioactivity in air, Radiation Surveillance Network, 1960–October 1966

2. Canadian Air and Precipitation Monitoring Program, October 1966 [1]

Radiation Protection Division
Department of National Health and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors surface air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport (figure 3). Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports by the Department of National Health and Welfare (*3–7*).

A summary of the sampling procedures and methods of analysis was presented in the November 1966 issue of *Radiological Health Data and Reports.*

[1] Prepared from information and data in the November 1966 monthly report "Data from Radiation Protection Program," Canadian Department of National Health and Welfare, Ottawa, Canada.

Surface air and precipitation data for October 1966 are presented in table 2. Specific radionuclide data are presented in table 3.

Table 2. Canadian gross beta radioactivity in surface air and precipitation, October 1966

Station	Air surveillance				Precipitation measurements	
	Number of samples	Activity, pCi/m³			Average concentrations (pCi/liter)	Total deposition activity (nCi/m²)
		Maximum	Minimum	Average		
Calgary	31	0.1	0.0	0.0	28	0.4
Coral Harbour	31	0.1	0.0	0.0	NS	NS
Edmonton	31	0.0	0.0	0.0	22	0.2
Ft. Churchill	18	0.0	0.0	0.0	38	0.8
Ft. William	31	0.1	0.0	0.0	14	1.1
Fredericton	11	0.1	0.0	0.0	15	1.1
Goose Bay	31	0.1	0.0	0.0	7	1.1
Halifax	31	0.1	0.0	0.0	14	1.2
Inuvik	31	0.0	0.0	0.0	9	0.2
Montreal	30	0.1	0.0	0.0	19	0.8
Moosonee	31	0.1	0.0	0.0	12	1.3
Ottawa	31	0.1	0.0	0.0	28	0.7
Quebec	31	0.1	0.0	0.0	16	1.0
Regina	31	0.1	0.0	0.0	47	0.3
Resolute	29	0.1	0.0	0.0	23	0.2
St. John's, Nfld.	31	0.1	0.0	0.0	7	0.8
Saskatoon	31	0.1	0.0	0.0	34	0.4
Sault Ste. Marie	31	0.1	0.0	0.0	16	1.7
Toronto	31	0.1	0.0	0.0	23	0.3
Vancouver	31	0.1	0.0	0.0	7	0.9
Whitehorse	31	0.0	0.0	0.0	6	0.2
Windsor	30	0.1	0.0	0.0	24	0.9
Winnipeg	20	0.1	0.0	0.0	49	1.0
Yellowknife	31	0.1	0.0	0.0	17	0.7
Network summary		0.1	0.0	0.0	21	0.8

NS, no sample

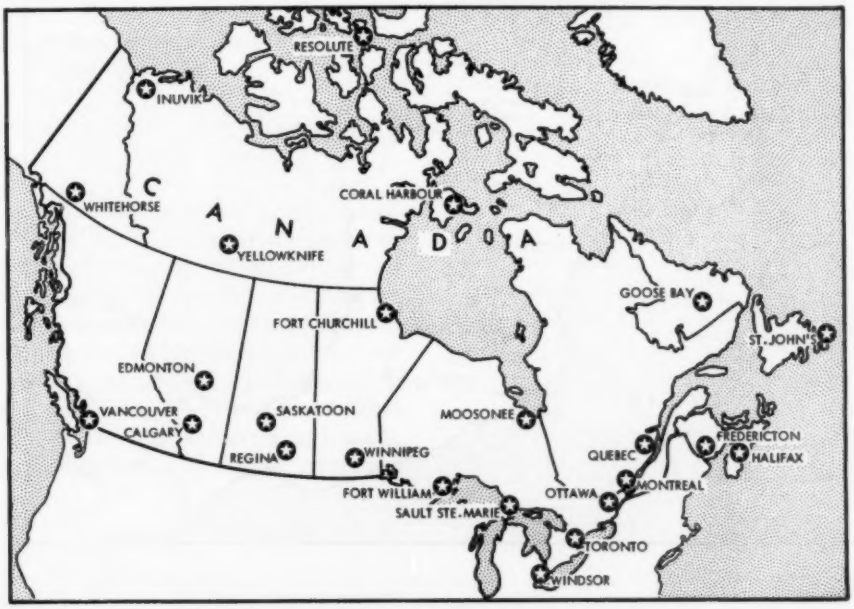

Figure 3. Canadian air and precipitation sampling stations

3. Mexican Air Monitoring Program October 1966

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the Comisión Nacional de Energía Nuclear (CNEN), México, D.F. From 1952 to 1961, the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN.

In 1961, the CNEN appointed its Division of Radiological Protection to establish a new Radiation Surveillance Network. In 1966, the Division of Radiological Protection was restructured and its name changed to Dirección General de Seguridad Radiológica (DRS). The network consists of 16 stations (figure 4), 11 of which are located at airports and operated by airline personnel. The remaining five stations are located at México, D.F., Mérida, Veracruz, San Luis Potosí, and Ensenada. Staff members of the DRS operate the station at México, D.F., while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Mérida, the Institute de Zonas Dsérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air through a high-efficiency 6- by 9-inch glass-fiber filter for 20 hours a day, 3 or 4 days a week at the rate of 1,000 cubic meters per day using high-volume samplers.

After each 20-hour-sampling period, the filter is removed and shipped via airmail to the Sección de Radioactividad Ambiental, CNEN, in México, D.F., for assay of gross beta radioactivity, alowing a minimum of 3 or 4 days after collection for the decay of radon and thoron.

Figure 4. Mexican air sampling station locations

The data are not extrapolated to the time of collection. Statistically, it has been found that a minimum of eight samples per month were needed to get a reliable average radioactivity at each station (*8*).

The maximum, minimum, and average fission product beta radioactivity concentrations in surface air during October 1966 are presented in table 4.

Table 4. Mexican gross beta radioactivity of airborne particulates, October 1966

Station	Number of samples	Gross beta radioactivity, pCi/m³		
		Maximum	Minimum	Average
Acapulco	7	0.1	0.1	0.1
Chihuahua	10	0.2	0.1	0.1
Ciudad Juárez	15	0.2	<0.1	0.1
Ensenda	15	0.6	<0.1	0.1
Guaymas	NS			
Guadalajara	10	0.1	<0.1	0.1
La Paz	18	0.1	<0.1	0.1
Matamoros	8	0.5	<0.1	0.1
Mazatlán	7	0.3	<0.1	0.1
Mérida	15	0.6	<0.1	0.1
México, D. F	4	0.1	<0.1	0.1
Nuevo Laredo	9	0.5	<0.1	0.2
San Luis Potosí	6	0.1	<0.1	<0.1
Tampico	6	0.1	<0.1	<0.1
Torreón	17	0.5	<0.1	0.2
Veracruz	15	0.2	<0.1	0.1

NS, no sample collected: station temporarily shut down.

4. Pan American Air Sampling Program October 1966

Pan American Health Organization and U.S. Public Health Service

Gross beta radioactivity in air is monitored by countries in the Americas under the auspices of the collaborative program developed by the Pan American Health Organization (PAHO) and the U.S. Public Health Service (PHS) to assist PAHO-member countries in developing radiological health programs. The sampling equipment and analytical services are provided by the National Center for Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network. The air sampling station positions are shown in figure 5.

Fresh fission products were identified during October in the samples in table 5. The October 1966 air-monitoring results from the participating countries are given in table 6. Levels were considerably higher than in September.

Decay indices of the various samples indicate that most of the gross beta radioactivity was probably from either the French test on September 24, 1966, or the French test on October 4, 1966.

Table 5. Fresh fission products in PAHO air samples October 1966

Location	Dates, October 1966	Maximum activity at time of collection (pCi/m³)	Date of maximum activity
Peru: Lima	[a] 1, 5, 13–29	31.37	18
Chile: Santiago	8–24, 26, 29–31	13.12	11
Venezuela: Caracas	[b] 24, 26–31	0.83	31
Argentine: Buenos Aires	1–6, 7–19, 21–27, 30, 31	19.91	1
Jamaica: Kingston	14, 17	0.53	14
West Indies: Trinidad	[c] 3, 4, 10–14, 26, 27	2.15	10
Columbia: Bogota	[d] 5, 6, 14–21, 26–31	0.80	17
Ecuador: Guayaquil	[e] 1–3, 5–13, 15–31	6.15	17

[a] No sample received for October 6–15, 30, 31.
[b] No sample received for October 1–20.
[c] No sample received for October 29–31.
[d] No sample received for October 7.
[e] No sample received for October 14.

Table 6. PAHO gross beta radioactivity in surface air October 1966

Station location	Number of samples	Gross beta radioactivity (pCi/m³)		
		Maximum	Minimum	Average [a]
Argentine: Buenos Aires	26	19.91	<0.10	3.07
Chile: Santiago	31	13.12	<0.10	<1.62
Columbia: Bogota	24	0.80	<0.10	<0.30
Ecuador: Guayaquil	28	6.15	<0.10	1.85
Jamaica: Kingston	22	0.53	<0.10	<0.12
Peru: Lima	14	31.37	0.94	9.56
Venezuela: Caracas	7	0.83	<0.10	<0.47
West Indies: Trinidad	19	2.15	<0.10	<0.57
Pan American summary	171	31.37	<0.10	<2.19

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If 10 percent or more of the samples from a station contain <0.10 pCi/m³, a less-than sign is placed before the average.

Figure 5. Pan American Air Sampling Program stations

5. Plutonium in Airborne Particulates July–September 1966

National Center for Radiological Health
Public Health Service

The Radiation Surveillance Network (RSN) of the National Center for Radiological Health, Public Health Service, located at Rockville, Maryland, is continuing routine analysis for plutonium in airborne particulates. These analyses were initiated during 1965 as part of the mission to establish, maintain, and operate a national surveillance network to measure radioactivity in the environment.

Air filters from 11 RSN stations are analyzed for plutonium. Each of the daily filters is counted for gross beta radioactivity and for gamma-ray emitters by gamma-ray scintillation spectrometry 4 to 5 days after collection. For plutonium analysis, a monthly composite is made of one-half of the individual sample from each station. Each composite, representing 10,000 to 20,000 cubic meters of air,

is analyzed by gamma-ray scintillation spectrometry prior to the plutonium analysis.

Details of the method of collection and radiochemical analyses were presented in an earlier report (*9*). Results for July through September 1966 are given in table 7.

Table 7. Plutonium in airborne particulates, July–September 1966 [a]

Station location	Plutonium radioactivity concentration in air (pCi/1,000 m³)		
	July	August	September
Alaska: Anchorage	0.088	0.049	0.057
Ariz: Phoenix	0.068	0.045	0.061
Colo: Denver	0.056	0.075	0.056
Hawaii: Honolulu	0.084	0.037	0.025
La: New Orleans	0.107	0.067	0.036
Md: Rockville	0.153	0.066	0.062
N. Y: Buffalo	0.143	0.073	0.084
N. C: Gastonia	0.114	0.051	0.052
S. Dak: Pierre	0.106	0.076	0.047
Tex: Austin	0.069	0.047	0.042
Wash: Seattle	0.050	0.046	0.027

[a] Plutonium includes plutonium-238, plutonium-239, and plutonium-240.

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(*9*) RUSSELL, J., H. LEVINE, and R. SCHNEIDER. Plutonium in airborne particulates, November 1965 through March 1966. Radiol Health Data Rep 7:483–484 (August 1966).

Section IV. Other Data

This section presents results from routine sampling of biological materials and other media not reported in the previous sections. Included are such data as those obtained from human bone sampling, bovine thyroid sampling, and environmental monitoring reports.

STRONTIUM-90 IN HUMAN BONE, JANUARY–MARCH 1966[1]

National Center for Radiological Health
Public Health Service

To obtain data on the concentration of strontium–90 in man by age and geographical region, the Public Health Service began collecting human bone specimens in late 1961. The target population includes children and young adults up to 25 years of age. Since strontium–90 in measurable amounts has been present in the global environment for not much more than a decade, and since major calcium accretion ceases by age 17 or 18, persons over 25 years old are of limited interest in the program. This has been confirmed by analyses of selected samples of people in older age groups, the results having shown their bone strontium–90 content to be low and age-independent *(1)*.

Although a few samples come from living persons as a result of surgical procedures, the majority are obtained post mortem. In the latter case, the specimens are limited to accident victims or persons who have died of an acute disease process that was not likely to impair bone metabolism. For analytical purposes, a sample of at least 100 grams of wet bone is desired. Generally, this amount is readily available from older children, but it presents some difficulties from the standpoint of infants and children under 5 years of age.

Most specimens received to date have been vertebrae and ribs. Efforts to collect long bones for comparison of results with British data have not been successful.

Laboratory procedures

The bones are analyzed at the Northeastern Radiological Health Laboratory of the National Center for Radiological Health, at Winchester, Mass. Sample collection and preparation are explained elsewhere *(2)*. Strontium–90 is measured by TBP extraction of its yttrium daughter, which is precipitated as an oxalate. The strontium–90 content is then calculated from the yttrium–90 activity *(3)*. For the purpose of maintaining analytical reproducibility, "blind" duplicate analyses are performed on 10 to 20 percent of the samples. To further check and maintain analytical accuracy synthetic "bone ash" samples (calcium phosphate spiked with strontium–90) are analyzed periodically and cross-check analyses are carried out quarterly in cooperation with the AEC Health and Safety Laboratory.

The analytical results for strontium–90 in individual bones from persons dying during the first quarter (January–March) of 1966, along with other pertinent data (place of residence, sex, bone type, and cause of death), are presented in table 1 in order of increasing age within each geographical sampling region. These regions are indicated in figure 1. Re-

[1] Period during which death or surgical procedure occurred.

Table 1. Strontium-90 in human bone, deaths and surgical procedures during January–March 1966

Sampling region and state of residence	Sex	Bone type [a]	Age at death [b] (years)	Cause of death	Strontium-90, pCi/g of:		
					Ash ±2σ error	Calcium	Bone
Northeast:							
N.Y.	F	V	1	Neuroblastoma	1.53 ±0.17	4.33	0.12
Maine	M	V	2	Hyperkalemia	2.97 ±0.21	8.12	0.29
R.I.	M	V,R,S	3	Congenital heart disease	1.76 ±0.22	4.97	0.11
Mass.	M	V	3	Thermal burns	1.64 ±0.14	4.51	0.16
Mass.	M	V	3	Acute leukemia	1.44 ±0.14	4.04	0.13
Mass.	F	V	4	Acute leukemia	1.29 ±0.14	3.75	0.08
Vt.	M	V	4	Mitral stenosis	1.23 ±0.17	3.48	0.12
N.Y.	F	V	4	Wilms's tumor	1.58 ±0.16	4.22	0.13
N.Y.	M	V	7	Acute leukemia	0.71 ±0.09	1.95	0.06
N.Y.	F	V	7	Thrombocytopenic purpura	1.30 ±0.10	3.48	0.15
(c)	M	V	7	(c)	1.40 ±0.13	3.95	0.14
Maine	F	V	8	Acute leukemia	1.29 ±0.10	3.60	0.12
Pa.	M	V	8	Head injury	0.72 ±0.09	1.96	0.05
Mass.	M	V	9	Congenital heart disease	0.77 ±0.08	2.08	0.08
R.I.	F	V,R,S,	9	Astrocytoma	0.88 ±0.08	2.35	0.13
N.Y.	M	V	10	Hemophilia	0.97 ±0.13	2.64	0.09
Mass.	F	V	10	Cystic fibrosis	0.99 ±0.09	2.69	0.10
Mass.	F	V	11	Acute leukemia	1.20 ±0.10	3.27	0.13
N.Y.	F	V	11	Myeloblastic leukemia	0.93 ±0.08	2.57	0.08
N.Y.	M	V	11	Brain tumor	1.09 ±0.14	3.14	0.14
Mass.	M	V	12	Asphyxia	1.21 ±0.09	3.24	0.15
N.Y.	F	V,R,S,	14	Glomerulonephritis	1.15 ±0.12	3.20	0.12
N.J.	M	V	15	Muscular dystrophy	0.64 ±0.08	1.71	0.06
N.Y.	M	V	17	Acute leukemia	0.75 ±0.09	2.00	0.10
Vt.	M	V	18	Asphyxiation	0.99 ±0.08	2.57	0.12
Mass.	M	V	18	Hydrocephalus	0.55 ±0.06	1.41	0.07
Pa.	M	R	19	Gunshot wound of chest	0.63 ±0.08	1.57	0.15
N.Y.	M	V	19	Carcinoma of testes	0.51 ±0.07	1.30	0.08
Pa.	M	V	21	Gunshot wound of buttock	0.82 ±0.08	2.11	0.11
Mass.	M	V	21	Auto accident	0.80 ±0.10	2.12	0.10
N.Y.	M	V	23	Sympathicoblastoma	0.78 ±0.07	2.07	0.11
Pa.	F	V	25	Gunshot wound of neck	0.66 ±0.08	1.71	0.10
Mass.	F	V	25	Cerebral laceration	0.66 ±0.07	1.72	0.10
Southeast:							
Ga.	M	V	3	Thermal burns	1.67 ±0.19	4.66	1.13
Md.	F	V	3	Stab wounds of neck	1.97 ±0.19	4.93	0.17
Md.	F	V	5	Stab wounds of neck	1.33 ±0.15	3.55	0.11
Md.	F	V	6	Thermal burns	1.23 ±0.12	3.47	0.13
Md.	M	V	12	Drowning	0.68 ±0.07	1.79	0.07
Md.	M	V	14	Gunshot wound of chest	0.90 ±0.07	2.37	0.13
Md.	M	V	17	Head injury	1.28 ±0.09	3.38	0.18
Md.	F	V	17	Laceration of aorta	0.73 ±0.08	1.88	0.11
Md.	M	V	17	Electrocution	0.96 ±0.08	2.49	0.13
Md.	M	V	20	Barbiturate overdose	1.03 ±0.09	2.71	0.15
Ky.	F	V	21	Mitral stenosis	0.95 ±0.09	2.52	0.13
Md.	M	V	21	Gunshot wound of chest	0.79 ±0.08	2.02	0.13
Md.	M	V	22	Gunshort wound of head	0.62 ±0.09	1.55	0.08
Md.	M	V	23	Subdural hematoma	0.59 ±0.06	1.53	0.09
Md.	M	V	23	Acute alcoholism	0.92 ±0.09	2.34	0.15
Ky.	M	V	24	Partial spinal cord transection	0.69 ±0.09	1.76	0.13
Central:							
Mich.	F	V	1	Tetralogy of Fallot	1.72 ±0.21	4.94	0.14
Ohio	M	V	1	Fanconi's syndrome	1.54 ±0.13	3.97	0.11
Minn.	M	V	3	Drowning	1.01 ±0.12	2.71	0.11
Wis.	M	V	3	Craniopharyngioma	1.64 ±0.15	4.70	0.15
Ohio	M	V	3	Acute leukemia	1.47 ±0.16	4.03	0.11
Minn.	F	V	3	Acute lymphoblastic leukemia	1.37 ±0.17	3.83	0.10
Wis.	F	V	5	Pneumonitis	0.81 ±0.10	2.25	0.08
Wis.	M	V	6	Tetralogy of Fallot	0.73 ±0.07	2.01	0.07
Wis.	F	V	7	Aplastic anemia	0.77 ±0.07	2.03	0.08
Wis.	F	V	8	Portal hypertension	1.11 ±0.16	3.05	0.11
Ohio	M	V	8	Abdominal injuries	1.14 ±0.13	2.11	0.17
Minn.	M	V	8	Rhabdomyosarcoma	1.44 ±0.14	3.92	0.14
Minn.	M	V	8	Auto accident	0.69 ±0.08	2.01	0.06
Wis.	M	V	10	Cerebellar tumor	0.86 ±0.12	2.30	0.07
Ohio	F	V	10	Bilateral lobular pneumonia	1.42 ±0.10	3.79	0.15
Wis.	F	V	12	Malnutrition	0.68 ±0.13	1.88	0.05
Ohio	M	V	13	Asphyxiation	1.00 ±0.07	2.59	0.18
Ohio	F	V	13	Acute cerebellar hemorrhage	1.22 ±0.08	3.18	0.18
Ohio	F	V	15	Brain injuries	0.76 ±0.06	1.97	0.14
Minn.	M	V	18	Diabetic acidosis	0.55 ±0.06	1.38	0.08
Ohio	F	V	19	Brain injury	0.55 ±0.06	1.41	0.13
Ohio	F	V	20	Anaphylaxis	0.67 ±0.12	1.70	0.14
Mich.	M	V	21	Rheumatic heart disease	0.51 ±0.07	1.32	0.07
Wis.	M	V	22	Ependymoma	1.13 ±0.15	3.10	0.09
Ohio	M	V	22	Meningeal sarcoma	0.85 ±0.08	2.22	0.08
Delta:							
La.	F	V	4	Acute leukemia	1.59 ±0.23	4.40	0.11
La.	M	V,R	10	Sickle cell anemia	2.39 ±0.16	6.53	0.24
La.	M	V,R	14	Head injury	1.08 ±0.07	2.86	0.15
La.	M	V,R	16	Lobar pneumonia	1.03 ±0.09	2.80	0.15
La.	M	V,R	17	Chronic glomerulonephritis	1.91 ±0.10	5.05	0.30
(c)	M	V	17	(c)	0.79 ±0.06	2.08	0.12

See footnotes at end of table.

Table 1. Strontium-90 in human bone, deaths and surgical procedures during January–March 1966—Continued

Sampling region and state of residence	Sex	Bone type [a]	Age at death [b] (years)	Cause of death	Strontium-90, pCi/g of:		
					Ash ±2σ error	Calcium	Bone
Northwest:							
Alaska	M	R	13	Surgical procedure	1.86±0.29	4.77	0.29
Alaska	F	R	17	Surgical procedure	1.26±0.17	3.25	0.53
Alaska	F	R	18	Surgical procedure	0.79±0.23	1.95	0.31
Alaska	F	R	19	Surgical procedure	0.95±0.31	2.42	0.37
Southwest:							
Calif	F	V,R,I	0	Stillbirth	0.48±0.07	1.36	0.04
(c)	F	V	1	(c)	0.67±0.11	1.83	0.06
(c)	M	V	1	(c)	0.70±0.12	1.96	0.06
Tex	M	V	19	Bullet wound of brain	0.69±0.08	1.77	0.09
Tex	F	V	20	Cerebral encephalopathy	0.64±0.06	1.68	0.09

[a] Type of bone: V, vertebrae; R, rib; I, ilium; S, sternum.
[b] Age given as of last birthday prior to death.
[c] Information not yet available.

ported values are given in picocuries of strontium–90 per gram of ash (the primary determination), per gram of calcium (for comparison with other data and for purposes of model development), and per gram of bone (as a rough indication of dose). Two-sigma counting errors are reported for the ash concentration.

Following the pattern of earlier reports, subsequent articles will continue to provide interpretation of the data at appropriate stages in the program (*2–4*).

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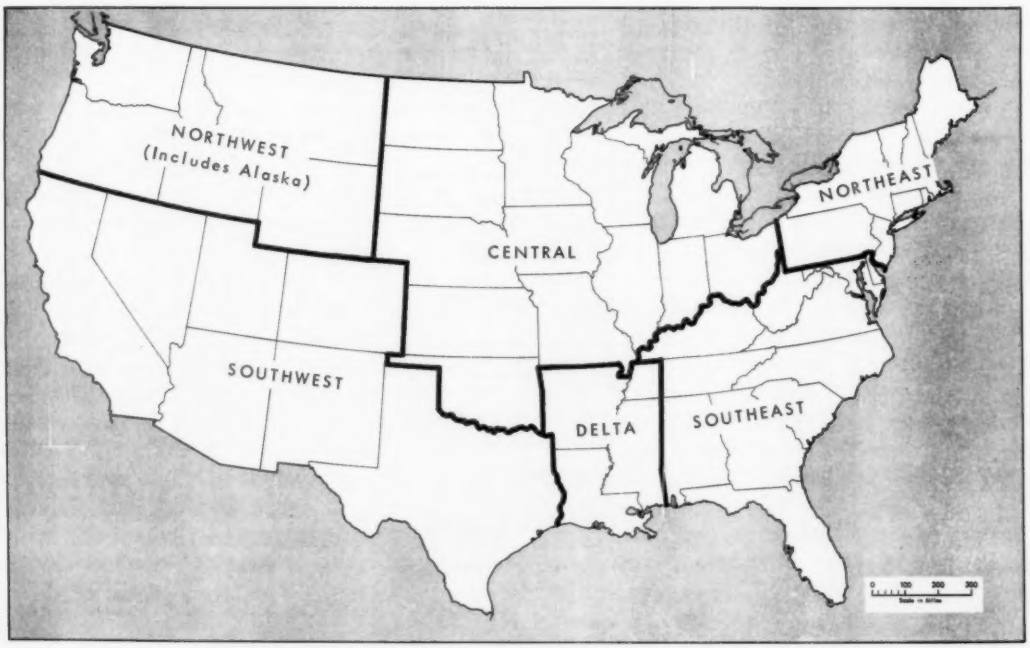

Figure 1. Geographical regions for human bone sampling

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semiannual reports on the environmental levels of radioactivity in the vicinity of major AEC installations. The reports include data from routine monitoring programs where operations are of such a nature that plant environmental surveys are required.

Releases of radioactive materials from AEC installations are governed by radiation standards set forth by AEC's Division of Operational Safety in directives published in the AEC Manual.[1]

Summaries of the environmental radioactivity data follow for the Hanford Atomic Products Operation, Pinellas Peninsula Plant, Savannah River Plant, and Shippingport Atomic Power Station.

[1] Part 20, "Standards for Protection Against Radiation," AEC Rules and Regulations, contains essentially the standards published in the AEC Manual and are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

1. Hanford Atomic Products Operation Calendar Year 1965[2]

Battelle Memorial Institute
Richland, Washington

The evaluation of results obtained from the Hanford environmental surveillance program for 1965 indicates that most of the environmental radiation dose received by the majority of persons living in the neighborhood of the Hanford project was due to natural sources and worldwide fallout rather than to Hanford operations.

Of the low-level wastes that are released to the environment from the Hanford plants, neutron-induced radionuclides present in reactor cooling water discharged to the Columbia River continued to be the source of greatest potential radiation dose to people in the environs. The primary pathways of exposure from this source are drinking water derived from the river, consumption of fish and waterfowl which inhabit the river, and foodstuffs grown on land irrigated with water pumped from the Columbia River downstream from Hanford.

Residents of Richland were supplied throughout the year with drinking water from the Columbia River. The radiation dose from drinking this water was estimated to be about 7 percent of the appropriate limit. The gastrointestinal tract is the limiting organ for the mixture of radionuclides present in drinking water pumped from the Columbia River. In Pasco and Kennewick, which are further downriver, the estimated doses from drinking water were, respectively, about 2.5 percent and <0.5 percent of the limit for the GI tract. The only persons who received radiation doses attributable to Hanford greater than those that resulted from the drinking water were the people who ate local fish or waterfowl.

The highly unlikely but plausible combination of circumstances that would result in the greatest dose to an individual from the radionuclides released by the Hanford plant is postulated as:

(1) the consumption of some 200 meals per year of fish caught downstream from the reactors,
(2) the consumption of meat and milk from cattle pastured, and fruit and vegetable grown, on irrigated farms in the Riverview District, and
(3) the consumption of drinking water from the Pasco system.

An individual with such habits could conceivably ingest enough radioactive materials of Hanford origin (mostly phosphorus–32) to provide an intake of about 12 percent of the maximum permissible rate of intake (MPRI)

[2] Summarized from Pacific Northwest Laboratory, Evaluation of Radiological Conditions in the Vicinity of Hanford for 1965, BNWL–316, September 1966.

specified by the International Commission on Radiological Protection (ICRP) for individuals in the general population, with bone as the critical organ. The resultant annual dose to the GI tract and whole body would then have been about 90 and 40 mrem, respectively, during 1965.

Iodine–131 in the Hanford environs remained at very low concentrations in 1965. The Chinese nuclear test on May 14 caused a brief increase in iodine–131, but concentrations soon returned to the low levels experienced during most of 1965. The postulated "maximum" annual dose from iodine–131 to the thyroid of a small child amounted to only about 4 percent of the radiation protection guide recommended for individuals by the Federal Radiation Council.

The Hanford plant [3] is located in a semiarid region of southeastern Washington State, where the average annual rainfall is about 16 cm (6 in.). This section of the State has a sparse covering of natural vegetation primarily suited for grazing, although large areas near the project have gradually been put under irrigation during the past few years. The plant site (figure 1) covers an area of about 1,300 km^2 (500 square miles). The Columbia River

[3] Operated during 1965 for the Atomic Energy Commission by the Battelle-Memorial Institute; Douglas-United Nuclear, Inc., and the General Electric Company.

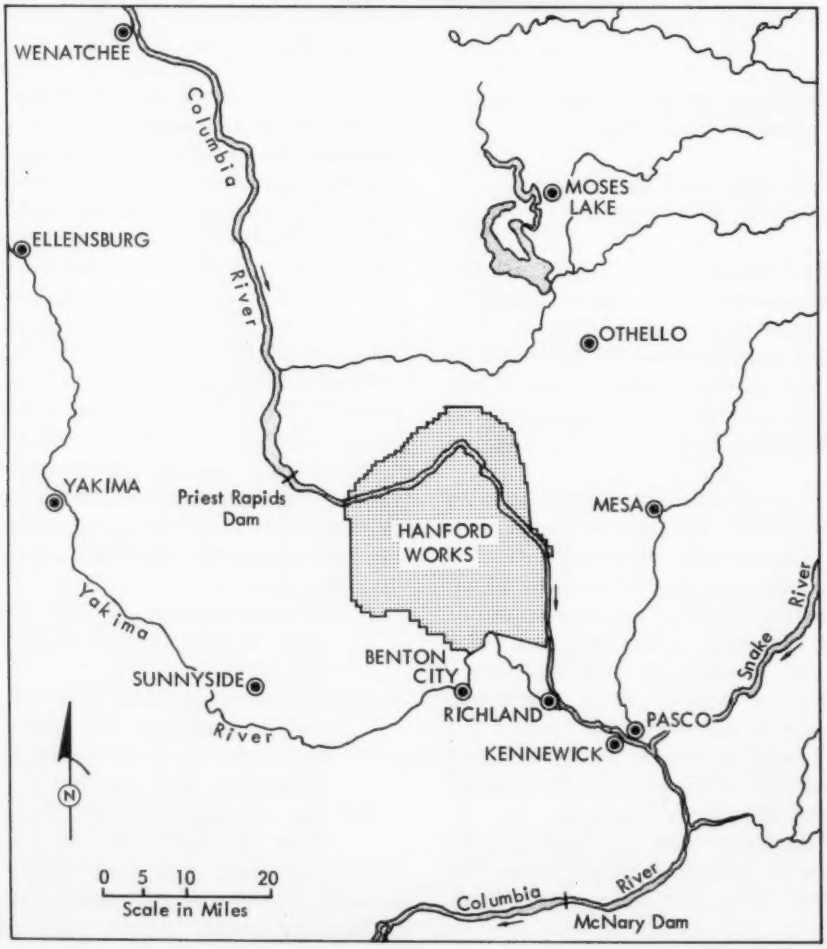

Figure 1. Hanford project environs

flows through the northern edge of the project and forms part of the eastern boundary. Near the plant production sites, the prevailing winds are from the northwest with strong drainage and cross winds causing distorted flow patterns. The meteorology of the region is typical of desert areas with frequent strong inversions occurring at night and breaking during the day to provide unstable and turbulent conditions.

The populated area of primary interest is the Tri-Cities (Richland, Pasco, and Kennewick) situated on the Columbia River directly downstream from the plant. Smaller communities in the vicinity are Benton City, West Richland, Mesa, and Othello; and these together with the surrounding agricultural area, bring the total population near the plant to about 80,000 people.

During the course of operation, various radioactive wastes are generated by the several plant facilities. High-level wastes are concentrated and retained in storage within the project boundaries. Controlled releases of low-level wastes, for which concentration and storage is not feasible, are made to the ground. Practices governing radioactive waste disposal at the Hanford Plant are described in the Hearings on Industrial Radioactive Waste Disposal held by the Joint Congressional Committee on Atomic Energy in 1959 (*1*).

It is the purpose of this report to present an evaluation of the combined off-project effects of the radioactive-waste-disposal practices of all Hanford contractors. Radiation protection practices, including the effects of radioactive waste disposal, are governed by AEC Manual Chapters 0524 and RL 0524 (*2*). The section to which this evaluation is addressed stipulates that radioactivity in effluents released to uncontrolled areas shall not result in a radiation dose to individuals exceeding 0.5 rem/yr to the whole body or gonads or 1.5 rem/yr to the thyroid or GI tract.

The significance of bone seekers such as phosphorus–32 and strontium–90 requires special consideration and treatment because the rate of intake of phosphorus–32 has not been specifically studied by the Federal Radiation Council (FRC) (*3*) in relation to a dose-equivalent for the bone or bone marrow.

Where the FRC does not provide direct guidance, they suggest that ICRP–NCRP (National Committee on Radiation Protection and Measurement) dosimetry methods be used (*4,5*). The ICRP values are used as a reference basc, because the ICRP–NCRP recommendations imply a more conservative rate of intake for phosphorus–32. Rather than introduce additional confusion associated with dose-equivalents for bone derived by different techniques, the data for bone seekers have been expressed in terms of a maximum permissible rate of intake (MPRI).

The MPRI is taken as the maximum permissible concentration (MPC) in water for a given radionuclide, as recommended by the ICRP for persons in the neighborhood of controlled areas, multiplied by the rate of water intake as defined for the standard man. This amounts to one-tenth of the MPC for continuous occupational exposure multiplied by intake rates of 2.2 liters/day or 800 liters/yr (for annual estimates). In the case of phosphorus–32 the MPRI is 16 μCi/yr.

The radiological units used throughout most of this report are mrems (dose-equivalent). For the nuclides of interest at Hanford, and the organs for which radiation doses (in mrads) and dose-equivalents (mrems) are calculated, the units rad and rem are numerically equal.

Included in this report are two types of measurements which are not necessarily relevant to dose evaluations. These are the concentrations of radionuclides in the Columbia River and concentration of iodine–131 in cattle thyroids which serve as trend indicators and as support for data used in dose calculations.

All of Hanford's production reactors use Columbia River water for cooling. At the older reactors, some elements present in the cooling water are transformed into radionuclides during the single pass through the reactors. In addition, radioactive materials formed on the surfaces of fuel elements and process tubes are eventually carried away by the cooling water to the river. H and F reactors were shut down permanently on April 21, 1965, and June 25, 1965, respectively.

In contrast with the older production reactors, the N reactor uses recirculating demineralized water as a primary coolant. Only a very small amount of radionuclides generated

in auxiliary systems, such as the control rod cooling water, are released directly to the river.

Many of the radionuclides formed in reactor cooling water are short-lived and decay rapidly after formation. In addition to radioactive decay, some fraction of most radionuclides is removed from the river water by sedimentation and by uptake by aquatic organisms. Also present in the river are radionuclides contributed by fallout from nuclear weapons testing.

Samples of river water were collected above the production areas at Vernita Ferry and below the areas at the Richland and Pasco water plant intakes, at McNary Dam, the Dalles Dam, and Bonneville Dam. Where possible, cumulative sampling equipment was installed and provided a more representative sample than the periodic grab samples obtained in the past. This cumulative sampling technique, however, makes it impractical to calculate the amounts of very short-lived nuclides; these must still be measured from grab samples. The average concentration of radionuclides measured routinely at Richland, Pasco, and Bonneville Dam are shown in table 1.

Table 1. Annual average radioactivity in Columbia River water, 1965

Radioactivity	Activity concentration (pCi/liter)		
	Richland	Pasco	Bonneville Dam
Total beta	12/counts/min.ml	[a]	[a]
RE+Y [b]	730	[a]	[a]
Sodium-24	3,100	[a]	[a]
Phosphorus-32	140	87	23
Chromium-51	7,000	4,100	1,700
Copper-64	2,500	[a]	[a]
Zinc-65	180	160	70
Arsenic-76	1,000	[a]	[a]
Strontium-90	1	[a]	[a]
Iodine-131	10	7	3
Neptunium-239	1,600	390	[a]

[a] Insufficient sampling data to provide a meaningful annual average.
[b] Rare earths plus yttrium.

Measurements on traverses across the river at Richland indicate a slightly nonuniform distribution of the longer-lived radiosotopes at this cross-section. Entries of the Yakima River some 16 km (10 miles) above Pasco and of the Snake River some 58 km (30 miles) above McNary Dam slightly influence the distribution of radionuclides at these two points. The magnitude of the influence varies with seasonal changes in the flow rate of the tributaries. Bonneville Dam is approximately 490 km (240 miles) below the Hanford reactors and represents the farthest downstream location where river water is routinely sampled for Hanford's environmental surveillance program.

The seasonal variation in flow rate of the Columbia River markedly affects the quantity of water available for dilution of reactor effluent released to the river. Also affected by the flow rate is the time required for a specific volume of water to move from one location to another. The annual average transport rate of selected radionuclides past the Bonneville Dam is given in table 2.

Table 2. Annual average transport rate past Bonneville Dam of selected radionuclides, 1962–1965

Radionuclide	Transport rate (Ci/day)			
	1962 [a]	1963 [a]	1964	1965
Phosphorus-32	13	12	12	11
Chromium-51	650	860	860	800
Zinc-65	29	28	44	49

[a] Rate of transport at Vancouver, Washington.

An estimate of the inventory of these radionuclides which exist in the ocean may be calculated by assuming an equilibrium between the rate of addition through the river and the rate of decay in the ocean. A constant rate of entry into the ocean equivalent to that indicated by the 1965 Bonneville Dam measurements would imply an inventory of about 230 curies of phosphorus–32, 32,000 curies of chromium–51, and 17,000 curies of zinc–65.

Radionuclides in drinking water

The city of Richland is the first community downstream from the Hanford reactors that uses the Columbia River as a source of drinking water supply. Pasco and Kennewick, a few miles farther downstream, also use the Columbia River as a source of drinking water. Continuous potable water samples were collected at the Richland water plant, and periodic samples were collected at Pasco and Kennewick. All of these samples were analyzed for the important individual radionuclides. The results of analyses of drinking water from these three cities are summarized in table 3.

Table 3. Annual average concentration of radioactivity measured in drinking water, 1965

Radioactivity	Radioactivity concentration (pCi/liter)		
	Richland	Pasco	Kennewick
Total beta	6.7 counts/min·ml	2.4 counts/min·ml	0.39 counts/min·ml
RE+Y [a]	80	27	[b]
Sodium-24	2,300	710	80
Phosphorus-32	100	28	10
Chromium-51	7,200	3,600	1,400
Copper-64	1,000	190	50
Zinc-65	100	70	<15
Arsenic-76	410	100	16
Strontium-90	1	1	[b]
Iodine-131	8	6	<2
Neptunium-239	1,600	760	60

[a] Rare earths plus yttrium.
[b] Insufficient data to provide a meaningful annual average.

The concentrations of short-lived radionuclides in the water at the time it is consumed are less than shown in table 3 because there is a significant transport time between the water plant and most consumers. The transport time may vary from hours to days depending upon the location of the customers on the distribution system and the water demand.

The calculated annual average dose to the GI tract and whole body and the percent MPRI for bone from sustained consumption of drinking water throughout the year at the three cities are presented in table 4.

Table 4. Calculated annual dose for selected organs from routine ingestion of drinking water, 1965 [a]

Location	Whole body (mrem)	GI tract (mrem)	Bone (percent of MPRI)	Thyroid (small child, 0.4 liter/day) (mrem)
Richland	2.5	35	0.8	19
Pasco	<1	13	0.3	15
Kennewick	<1	1	<0.1	<5

[a] Here and elsewhere in this report where a dose (mrem) from an ingested nuclide is expressed, the determination is made from parameters used by the ICRP to translate dose rates into maximum permissible concentrations for drinking water. In most cases, the estimated annual intakes of individual radionuclides were multiplied by conversion factors derived from the ICRP parameters and published by Vennart and Minski (*9*).
Note: The "standard man" average intake rate of 1.2 liter/day was used in this calculation(*4*).

The GI tract dose of Richland and Pasco residents was significantly lower in 1965 than in the past years (*6,7*).

This is primarily attributed to the permanent shutdown of the three Hanford reactors.

An unusual release of radioactive materials occurred on September 29, 1965, from the Plutonium Recycle Test Reactor (*8*). The minor effects of this release are included in the annual averages of drinking water data, and in the corresponding radiation doses from the consumption of drinking water.

Radionuclides in fish and waterfowl

The Columbia River is popular for sports fishing above and below the Hanford plant, and the fish that feed downstream from the reactors acquire some radionuclides from the reactor effluent. White fish are the sports fish that usually contain the greatest concentration of radioactive materials. Further, they can be caught during winter months when other sports fish are difficult to sample. For these reasons, whitefish are sampled most intensively to follow trends.

The average concentrations of phosphorus–32 and zinc–65 in whitefish sampled downstream from the reactors during 1965 were 200 pCi/g and 27 pCi/g of flesh, respectively. These concentrations were substantially lower than those observed in previous years (*6,7*), owing in part to the retirement of three Hanford reactors.

The quantities and kinds of fish caught by local fishermen have been estimated previously from surveys carried out by personnel of the State of Washington, Department of Game. Additional dietary data collected during 1965 did not change these estimates. Those individuals who probably ingest the largest amounts of phosphorus–32 are fishermen who claim to eat bass, crappie, perch, and catfish as often as three to five times a week. This large number of fish meals indicates an annual intake of about 40 kg (about 90 pounds) of fish. On the basis of the 40 kg of fish consumption claimed by the "maximum individual" (200 fish meals/year), the intake of phosphorus–32 during 1965 could have been approximately 1.7 μCi, or approximately 11 percent of the MPRI for bone as the critical organ.

Many persons have been counted in the Hanford whole-body counter, including some avid fishermen. Amounts of zinc–65 detected in these people were much less than expected on the basis of their stated consumption of fish. These results supported the findings of past

years which suggested that fishermen tend to over-estimate their fish consumption. Therefore, the actual ingestion rates of both phosphorus–32 and zinc–65 are undoubtedly substantially lower than currently postulated from the fishermen's estimates.

Migratory waterfowl, such as ducks and geese, which have utilized the Hanford section of the Columbia River and the swamps and ponds within the project boundaries may contain phosphorus–32, zinc–65, and small amounts of other radionuclides. Some of these waterfowl remain in this general area throughout the year. Seventy-five of the water fowl samples collected during 1965 had concentrations of phosphorus–32 less than 50 pCi/g of flesh (wet weight), 20 samples were above 50 pCi/g but less than 500 pCi/g, and the remaining 3 samples were over 500 pCi/g. The maximum concentration of phosphorus–32 was 950 pCi/g. However, as a potential source of this radionuclide to people, the waterfowl are of much less significance than the fish because they cannot be harvested in such large numbers by individuals and because of "dilution" by large flights of migrating birds that move through the region at the time of the year when hunting is allowed.

Radionuclides in marine organisms

Zinc–65 and phosphorus–32 are the only radionuclides in the reactor effluent that are found in sufficient abundance beyond the mouth of the Columbia River to be of radiological interest. Oysters have been found to contain higher concentrations of zinc–65 than other common seafood organisms.

Annual average concentrations of zinc–65 have decreased over the past 2 years, while phosphorus–32 concentrations have remained at about the same level during the same period of time (*6,7*). The average concentrations in samples taken throughout 1965 were 40 pCi/g and 4 pCi/g of zinc–65 and phosphorus–32, respectively.

Consumption of oysters containing these concentrations at the rate of one meal (230 g or about one-half pound) per week would result in an annual dose of about 5 mrem to the GI tract and 3 mrem to the whole body. These intakes represent 0.3 percent of the MPRI for bone as the critical organ.

Radionuclides in the atmosphere

At Hanford, gaseous waste from the chemical separations facilities is released to the atmosphere through 70m-high (230 feet) stacks after most of the radioactive materials have been removed by filtration and scrubbing. These radioactive materials are primarily associated with process vessel off-gases. Ventilation air from laboratory and reactor buildings contains comparatively minor amounts of radioactive materials under normal operating conditions.

Measurements of airborne iodine–131 were made routinely at numerous locations within the Hanford reservation and around the plant perimeter. The results of iodine–131 measurements for the past few years are summarized in table 5.

Table 5. Annual average iodine-131 concentrations in the atmosphere, 1962–1965

Location	Distance from separation stacks (miles)	Iodine-131 (pCi/m³)			
		1962	1963	1964	1965
Prosser Barricade [a]	14	[b]	[b]	0.02	0.03
Benton City	20	0.08	0.03	0.06	0.03
Richland	23	0.04	0.02	0.02	0.02
Pasco	32	0.08	0.02	0.01	0.03

[a] Installed during October 1963.
[b] Insufficient sampling data to provide a meaningful annual average.

The four locations listed in table 5 lie within a 45° sector southeast to south of the separations center. Such concentrations sustained in inspired air imply an annual dose to the thyroid of the "standard man" of less than 1 mrem.

Air filter sampling is maintained at several locations within the Hanford reservation and around the plant perimeter. Air filter results are not used in estimating exposure but serve to illustrate the trends in atmospheric contamination. Sudden changes in concentration are used to signal the need for shifted emphasis in other portions of the environmental monitoring program related to atmospheric contamination.

Radionuclides in milk and produce

The radioactivity found in locally grown agricultural produce can be influenced by deposition of airborne radionuclides or by irriga-

tion with river water containing reactor effluent radionuclides. The chemical separations facilities are generally the principal local source of airborne radionuclides. The closest farming area to the separations facilities is about 21 km (13 miles) away.

In addition to the radioactive materials released to the Columbia River from the Plutonium Recycle Test Reactor on September 29, 1965, *(8)*, radioiodine and noble gases were released to the atmosphere. The minor effects of the atmospheric release are included in the annual averages of environmental sample data, and in the corresponding radiation dose estimates.

Most irrigated farms near the Hanford plant use water drawn from the Yakima River, or from the Columbia River above the project. There are, however, two small areas which regularly take water from the Columbia River downstream from the reactors for irrigation. They are the Ringold farms and the Riverview district west of Pasco, located respectively 24 and 48 km downstream from the reactors.

The principal products from the larger farm plots are hay, fruit, beef, and dairy products. This area is centered 48 km (30 miles) southeast of the chemical separations plants. Another agricultural area near the project is Benton City, located on the Yakima River about 20 miles (32 km) directly south of the separations facilities.

A comprehensive milk surveillance program maintained during 1965 included samples from local farms and dairies and from commercial supplies available to people in the Tri-Cities. The concentrations of radionuclides found in milk sold by commercial outlets were similar to that reported by the U.S. Public Health Service and the Washington State Department of Health. Milk from local farms irrigated with water drawn from the river downstream from the reactors contained phosphorus–32 and zinc–65 as well as fission products of fallout origin.

Generally, the average concentration of iodine–131 in both local and commercial milk was at or below the analytical limit of 3 pCi/liter except for a brief increase during the late spring (following the Chinese nuclear weapons test on May 14, 1965) and again during the fall months (following a small, transient increase in the release rate of iodine–131 from a chemical separations facility during the latter part of October). The maximum concentration of iodine–131 observed in milk was 26 pCi/liter on November 9, 1965.

Dairy farms in the Ringold and Riverview area that utilize the Columbia River for irrigation of pasture land and hay fields produce milk containing both phosphorus–32 and zinc–65. During 1965 the average concentration of phosphorus–32 in milk from these farms was about 490 pCi/liter (much lower than the 1964 average of 1,600 pCi/liter) and the concentration of zinc–65 was 480 pCi/liter. The highest concentration of phosphorus–32 in milk (1,000 pCi/liter) was observed during early September, a period of heavy irrigation and rapid growth of pasture grass. Commercial milk distributed in the Tri-Cities usually does not contain phosphorus–32 and zinc–65 because it is obtained principally from areas not irrigated with Columbia River water.

Adult residents consuming milk (1 liter/day) obtained from the Ringold-Riverview area would receive an annual dose from phosphorus–32 and zinc–65 amounting to about 4 mrem to the GI tract and 2 mrem to the whole body. The intake of phosphorus–32 and zinc–65 would be equal to about 0.8 percent of the MPRI for bone. The intake of iodine–131 would have resulted in a dose of about 2 mrem to the thyroid.

Miscellaneous fresh farm produce was sampled periodically for radioanalysis during the 1965 growing season from local farms and commercial outlets. Results of these measurements were similar to those of previous years (*6,7*) and indicated that only small quantities of radionuclides are present in locally grown produce.

The concentrations of iodine–131 found in samples of fresh vegetables collected from local farms and markets during the period of May through September 1965 were less than or approximately equal to the analytical limit of 0.05 pCi/g. There was no significant difference noted in concentrations found in local farm produce and in produce purchased from commercial outlets. If these fresh vegetables had been consumed at the rate of 100 g/day

throughout the 5-month growing season, the average annual intake from this source would have been about 730 pCi for iodine–131. Such an intake would imply an annual dose of about 1 mrem to the thyroid of a typical adult Richland resident.

Concentrations of iodine–131 in cattle thyroids

Thyroids of cattle are collected periodically from slaughter houses in Moses Lake, Yakima, Walla Walla, Wenatchee, and Pasco, and are sent to Hanford for radioanalysis. The average concentrations measured in beef thyroids were generally at or below the analytical limit of 5 pCi/g for iodine–131 during most of 1965, except for a brief period in the late spring following the May 14, 1965, Chinese nuclear weapons test. The maximum concentration of iodine–131 in bovine thyroids was 150 pCi/g from one sample collected in November at Pasco.

External radiation

Ionization chambers are stationed on the Hanford reservation and in Richland to estimate the gamma radiation exposure from external sources. Measurements in air 1 meter above ground during 1965 averaged about 0.32 mR/day or 120 mR/yr at Hanford and about 0.30 mR/day or 110 mR/yr at Richland, somewhat lower than measured during the past 2 years *(6,7)*. Essentially all of this exposure is from natural background and worldwide fallout from nuclear testing.

Direct radiation measurements are also made in the Columbia River at several locations with pocket-type ionization chambers submerged 0.6 to 1.5 m (2 to 5 feet) below the surface of the water. Exposure rates are higher in the river than overground because of the presence of gamma emitters (especially sodium–24) in reactor effluent. In the vicinity of Richland, the average exposure rate in the water during the months of April through October was about 2 mR/day. A person swimming or boating in the river for a total of 240 hours during the year could have received a whole-body exposure of about 20 mR.

An estimate of the external radiation exposure received by people that fish from the shore in the vicinity of the Hanford project is complicated by the daily fluctuation in the level of the river, but the exposure rate at the river's edge during 1965 was lowest during the freshet in late June and highest during low river flow rates in the fall months. Recent measurements of the gamma-ray spectrum indicate that zinc–65 accumulated by algae growth on the subtrate at the river's edge is responsible for a major portion of a fisherman's radiation exposure. Assuming that an avid fisherman spent as many as 500 hours on the river bank in the vicinity of Richland during 1965, his external exposure could have been about 15 mR.

Radioactive wastes released to ground

Liquid wastes from the chemical separations areas are routed to various facilities dependent upon their burden of radionuclides. High-level wastes (normally containing concentrations greater than 100 μCi/ml) are stored in underground concrete tanks lined with steel. Intermediate level wastes (ordinarily containing concentrations in the range of 5×10^{-5} μCi/ml to 100 μCi/ml) are sent to underground "cribs" from which they percolate into the soil. The areas selected for intermediate waste disposal and high level waste storage have soil with good ion exchange capacity and ground water depths of 50 to 100 m (165 to 330 feet). Low-level wastes (usually containing less than 10^{-5} μCi/ml) are sent to depressions in the ground where surface ponds or "swamps" have been formed as a result of the continuous addition of the relatively large volumes of water. Wells have been drilled in and around crib and tank storage areas to detect any leaks in the tanks and to measure radionuclides that have reached the ground water. Vitually all of the radionuclides present in the ground water have been introduced with liquids sent to the cribs. The bulk of this radioactive material is ruthenium-rhodium–106. A substantial amount of tritium has also been sent to the ground with the intermediate level liquid wastes from the separations plants.

In all probability, some tritium and ruthenium-rhodium–106 originating at the chemical processing areas is now entering the Columbia River. However, the contribution of these nuclides is too small to be detectable in the

riverwater and any exposure from them is therefore negligible.

Fallout from nuclear weapons testing

In addition to the radiation dose received by residents of the Hanford environs from Hanford-originated radionuclides and from natural background radiation, a dose increment due to fallout nuclides is also received. Locally this increment is below the national average because of the low rainfall in this region (6.3 inches/year). Measurements of fallout, like measurements of natural background radiation, are necessary to place the radiation dose resulting from Hanford operations into proper perspective. The fallout nuclides of interest during 1965 were tritium, strontium–90, iodine–131, and cesium–137. Although a small transient increase in iodine–131 concentrations was observed in May and June (following the Chinese nuclear weapons test), the resulting thyroid dose was negligible.

Tritium (another fallout radionuclide), although occasionally detectable in Columbia River water, was at such low levels (near or below the detection level of 1,000 pCi/liter) that routine consumption of water obtained from the Columbia River implied an annual dose to the whole body of the "maximum" individual of less than 1 mrem. No tritium was detectable by routine methods in any other environmental media.

Concentrations of strontium-90 measured in milk produced locally are similar to concentrations found in commercial milk produced in areas that are remote from the Hanford plant. Strontium–90 found in milk from local farms averaged about 8 pCi/liter. The concentration of cesium–137 in milk analyzed at Hanford was generally near the analytical limit of 30 pCi/liter. Worldwide fallout is the principal source of strontium–90 and cesium–137 in milk.

About 10 percent of the total intake of strontium–90 by local residents during 1965 came from drinking water obtained from the Columbia River. As in the case of milk, this strontium–90 was of fallout origin.

Based on the same dietary information used in other sections of this report, the total intake of strontium–90 during 1965 was about 0.007 μCi for the "maximum" individual and 0.006 μCi for the typical Richland resident. The total intake of cesium–137 during 1965 was about 0.06 μCi for the "maximum" individual and about 0.04 μCi for the typical Richland resident. The estimated annual dose from fallout radionuclides present in the Hanford environs is given in table 6.

Table 6. Annual radiation dose from fallout radionuclides, 1965

Radionuclide	Organ	Radiation dose (mrem)	
		Maximum individual	Average Richland resident
Strontium-90	GI tract	1	1
	Whole body	1	1
	Bone	(2 percent MPRI)	(5 percent MPRI)
Cesium-137	GI tract	1	1
	Whole body	2	1
	Bone	(0.2 percent MPRI)	(0.3 percent MPRI)

Radiation exposure summary

It is not possible to determine the precise radiation dose received by every individual because of variations in the kind and quantity of food consumed, variations in sources of food supply, and many variations in personal living habits. These inherent variations among individuals require a somewhat subjective approach when estimating the probable radiation exposure in relation to various established limits. The FRC has provided two sets of guides against which doses from environmental sources may be judged; that is, one for the individuals that receive the greatest dose, and the other for the average dose received by the general population (taken as one-third of that set for individuals). For the Hanford environs, doses from the various sources described in the preceding sections have been compiled in two ways to allow comparisons with guides for both the individual and the general population. In one case a hypothetical, but plausible, individual has been assigned dietary and other habits that would result in what would seem to be the greatest rational dose. For the general population a dose has been estimated for what is called the typical Richland resident.[4]

[4] The infeasibility of obtaining completely realistic dietary data for the typical resident leads to these assumptions: no radioactive decay takes place during the transport of drinking water to the user, there is no loss of radioactivity from food during preparation, and results of USDA dietary surveys represent the diet of the typical resident of the Hanford environs.

Some residents may receive a larger dose than calculated for the typical Richland resident but it is improbable that any would receive as much as that calculated for the "maximum" individual. Included in this intermediate group are families that subsist largely on foodstuffs produced on farms irrigated with water taken from the Columbia River downstream from the reactors.

The "maximum" individual

Attempts have been continued to identify the individuals living in the Hanford environs that receive the greatest radiation dose. Experience accumulated from the environmental surveillance program indicates such individuals are undoubtedly persons that frequently eat fish caught locally in the Columbia River, and foodstuffs grown on farms irrigated with Columbia River water. Additional data collected during 1965 continued to support the assumption that fish, consisting mainly of crappie, perch, bass, and catfish caught near Burbank (figure 2) are the most important source of radionuclides for the "maximum" individual. On the basis of an assumed consumption of 200 meals/year and radiochemical analyses of such fish, the intakes of phosphorus–32 and zinc–65 for the "maximum" individual during 1965 would have amounted to 1.7 and 0.4 μCi, respectively. Whether this amount of fish was actually eaten by the individual was not confirmed. However, other persons reporting an unusually high consumption of local fish were counted in the whole body counter and were found to have far less zinc–65 deposited (by a factor of about 0.03) than predicted on the basis of their estimates of the quantities of fish eaten. As a basis for calculating the intake of radionuclides from fish, we have continued to use the maximum reported consumption of 200 fish meals per year.

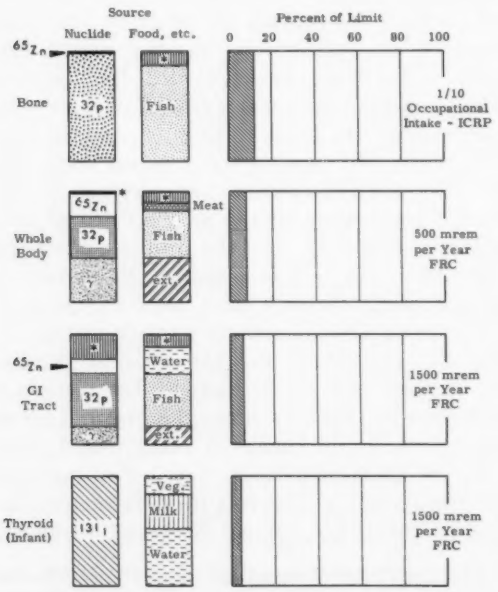

Figure 2. Estimated dose to "maximum" individual 1965

The consumption rates of other foods for the hypothetical "maximum" individual are based on the maximum intakes described in various dietary surveys. It is assumed that each day this individual consumes 2 liters of water from the Pasco system, 1 liter of milk, 230 grams of beef, and nearly 200 grams of fresh leafy vegetables (in season), all produced on river irrigated farms in the Riverview District. The composite doses from these sources are illustrated in figure 2.

In the case of the thyroid gland, it is probable that the maximum exposure occurred in small children because of the relatively small thyroid mass in which the iodine–131 accumulates. The thyroid of a small child is assumed to weigh 2 grams, compared with 20 grams for the adult. On the basis of a daily intake of 1 liter of milk, 50 grams of fresh leafy vegetables produced in the Riverview District, and 0.8 liter of water from the Pasco system, the estimated annual intake of iodine–131 was about 3,400 pCi for a small child in 1965. Such an intake would result in a thyroid dose of 58 mrem or 3.9 percent of the FRC radiation protection guide for individuals.

The typical Richland resident

The vast majority of people who live in Richland, Pasco, and Kennewick obtain their food from local commercial stores (rather than directly from farms) and consume little or no fish caught from the Columbia River. The principal sources of radionuclides ingested by these people are from worldwide fallout and from

drinking water obtained from the Columbia River. It is assumed that the contribution from fallout of strontium–90 and cesium–137 is the same in all three cities. These contributions were estimated with the use of data obtained from dietary surveys made elsewhere in the United States and reported by the Federal Radiation Council *(3)*, but adjusted on the basis of the concentration in milk sold in local stores during 1965. The estimated annual intakes of strontium–90 and cesium–137 during 1965 represented about 5 percent and 0.3 percent, respectively, of the MPRI (with bone as the critical organ).

The contribution from Hanford-created radionuclides in drinking water is substantially different for the three cities as discussed previously in the section on radionuclides in drinking water. The GI tract dose in Richland was greater than in the cities farther downriver because the short-lived nuclides are in greater abundance. As shown in figure 3, the estimated dose to typical Richland residents for 1965 was about 35 mrem, or 7 percent of the maximum permissible dose. The contribution to the GI tract dose from other sources was relatively insignificant and, conversely, the concentrations in water of bone-seeking radionuclides, such as phosphorus–32 and strontium–90, were so low that drinking water did not contribute any significant radiation dose to the bone.

For calculating a dose to the thyroid gland, the most appropriate sample of the exposed population would appear to be small children living in Richland who drank water from the municipal system (0.4 liter/day), milk (0.6 liter/day) obtained from the local stores, and fresh vegetables (25 g/day) obtained from local markets. The total intake of iodine–131 during the year from these sources would be about 1,800 pCi, or an average of about 5 pCi/day. This is in the middle of the FRC Range I and indicates a radiation dose of 30 mrem for 1965 (figure 3).

The estimated whole-body dose (figure 3) of the average Richland resident from radionuclides of Hanford origin was 5 mrem. Whole-body doses from natural background (excluded from the FRC Guide) and fallout sources in this region are estimated at about 110 mrem/year, and 2 mrem/year respectively.

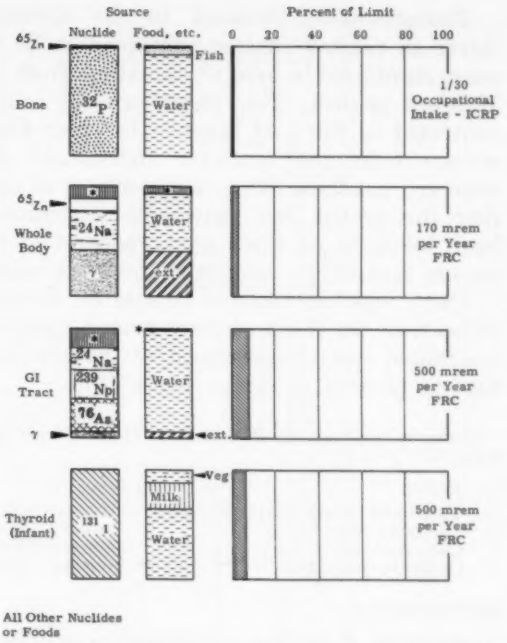

Figure 3. Estimated dose to "typical" Richland resident, 1965

Table 7 provides a summary of radiation doses estimated for individuals and population groups residing in uncontrolled areas in the Hanford environs.

Table 7. Summary of radiation doses in uncontrolled areas of the Hanford environs, 1965[a]

Organ	Maximum individual			Average Richland resident		
	Annual dose (mrem)	Limit (mrem)	Percent of limit	Annual dose (mrem)	Limit (mrem)	Percent of limit
GI tract	86	1,500	6	37	500	7
Thyroid (infant)	58	1,500	4	30	500	6
Whole body	38	500	8	5	170	3
Bone	[b]	[b]	[c] 12	[b]	[b]	[c] 0.9

[a] Represents individuals or population groups residing in uncontrolled areas near the Hanford plant.
[b] Insufficient sampling data to provide a meaningful annual average.
[c] Value represents percent of maximum permissible rate of intake specified by the International Commission on Radiological Protection for individuals in the general population.

Conclusions

During 1965, the environmental surveillance program of the Hanford environs again showed that the amounts of radioactive materials present were well within nationally accepted limits at all times and that releases of radioactive wastes were well controlled.

Phosphorus–32 released to the Columbia River in reactor effluent continued to be the most significant source of radiation from the Hanford project. This phosphorus–32 is concentrated in fish that inhabit the river downstream from the reactors. Individuals who regularly eat these fish as a major part of their diet throughout the year could conceivably have taken in as much as 11 percent of the annual permissible amount of this bone seeker.

There was one unusual release of radionuclides from the Hanford plant during 1965 that warranted special assessment of the radiation dose to persons in the environs (*8*).

Previous coverage in *Radiological Health Data and Reports:*

Period	Issue
Third and fourth quarters 1961	October 1962
Calendar year 1962	January 1964
Calendar year 1963	January 1965
Calendar year 1964	February 1966

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(*2*) U.S. ATOMIC ENERGY COMMISSION. Permissible levels of radiation exposure. AEC Manual, Chapter 0524 (1958); codes and standards for health, safety and fire protection. AEC Manual, Chapter 0550 (1961), Washington, D.C.

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(*4*) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Report of Committee II on permissible dose for internal radiation (1959) with bibliography for biological, mathematical, and physical data. Health Physics 3:1–380 (1960).

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(*7*) BATTELLE MEMORIAL INSTITUTE. Evaluation of radiological conditions in the vicinity of Hanford for 1964, BNWL–90. R. H. Wilson, Editor, General Electric Company, Richland, Washington (July 1965).

(*8*) U.S. ATOMIC ENERGY COMMISSION, HEALTH AND SAFETY DIVISION. Final investigative report of fuel element rupture test facility incident, RLOO–AEC. AEC Health & Safety Divsion, New York, N.Y. 10014 (September 1965).

(*9*) VENNART, J., and M. MINSKI. Radiation doses from administered radionuclides. British J Radiology 35:372–387 (1962).

2. Pinellas Peninsula Plant January–June 1966[5]

General Electric Company
St. Petersburg, Florida

Pinellas Peninsula Plant, shown in figure 4, is an electronic component production facility. The plant maintains an environmental monitoring program to measure the levels of radioactive environmental contamination associated with plant effluents. These measurements serve as an index of the effectiveness of the plant's contamination control measures. Effluent radioactivity concentrations and associated atmospheric and stream dilution factors indicate that the offsite radioactivity concentrations encountered by the general population are substantially lower than the guides for continuous non-occupational exposure established by AEC and documented in the AEC Manual.

Sewer effluent monitoring

A combined sewer effluent sample is obtained daily near the perimeter of the plant's property. During the sampling period 8 of 124 samples analyzed showed concentrations of tritium greater than the minimum detectable level of 9.0×10^4 pCi/liter. The maximum concentration, 1.86×10^6 pCi/liter, was detected on February 7, 1966. Calculations based on radioactivity releases from the process waste system, and the plant's water discharges, indicate that the average tritium concentration in the combined sewer effluent for the first half of 1966 was less than 2.02 percent of the radioactivity concentration guide for continuous nonoccupational exposure.

[5] Summarized from "Environmental Monitoring, January 1 through June 30, 1966," General Electric Company, Pinellas Peninsula Plant, St. Petersburg, Florida.

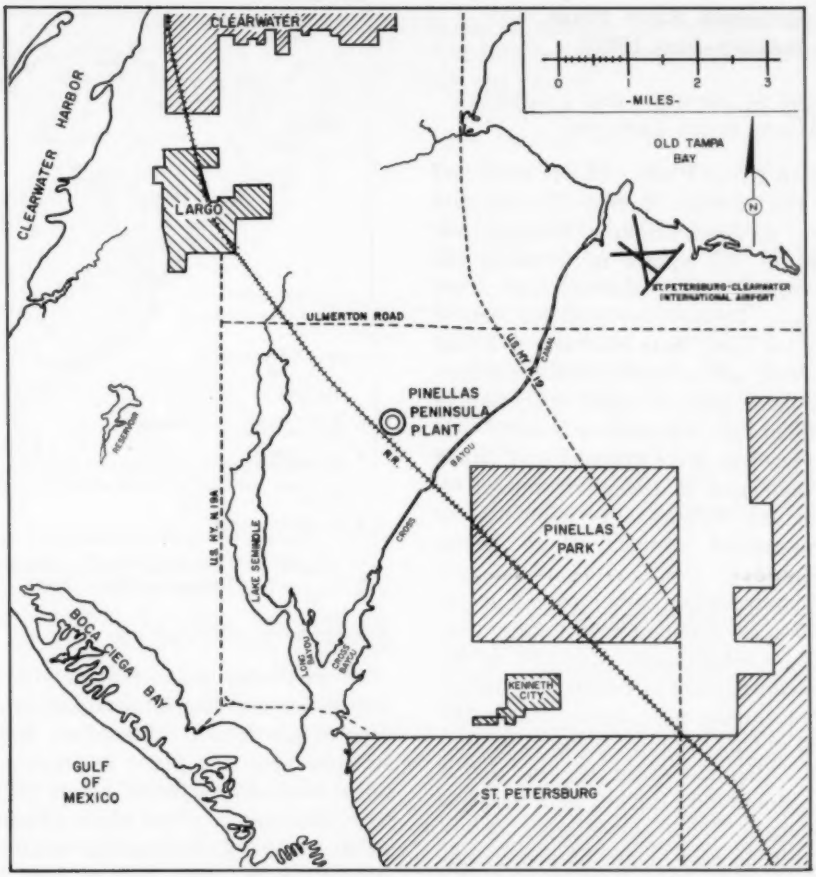

Figure 4. Location of the Pinellas Peninsula Plant

Air monitoring

Air samples are obtained periodically in areas up to 2 miles downwind from the exhaust stack. Analysis of the one sample collected during the sampling period revealed no detectable amounts of tritium gas (9,600,000 pCi/m ^{3}) or tritium oxide, above the minimum detectable levels of 9.6 x 10^6 and 5.0 x 10^3 pCi/m^3, respectively.

Surface water sampling

Surface water samples are collected at monthly intervals at selected locations within 8 miles of the plant. The sampling areas are determined by interrelating the concentrations of radioactivity in exhaust stack effluent with meteorological data. Levels of tritium oxide in the 57 surface water samples analyzed during the sampling period were less than the minimum detectable level of 9.0 x 10^4 pCi/liter.

Milk sampling results

Eighteen samples of raw milk were collected from local dairy farms and analyzed by the Florida State Board of Health during the first half of 1966. No detectable concentrations greater than 9.0 x 10^4 pCi/liter of tritium were evident.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
Calendar year 1963	September 1964
January–June 1964	February 1965
July–December 1964	August 1965
January–June 1965	February 1966
July–December 1965	August 1966

3. Savannah River Plant January–June 1967[6]

E.I. du Pont de Nemours and Company
Aiken, South Carolina

The Savannah River Plant (SRP), built and operated for the Atomic Energy Commission by E.I. du Pont de Nemours and Company, occupies an area of 312 square miles along the Savannah River, 22 miles downstream from Augusta, Georgia. Production facilities include a fuel preparation area, four reactors, two fuel separations areas, and a heavy-water production plant. A basic goal in plant operation is total containment of radioactive waste. Although some very low-level gaseous and liquid wastes are discharged to the environment in controlled releases, dispersal is adequate to ensure environmental concentrations below recommended guides.

The DuPont environmental monitoring group has maintained a continuous monitoring program since 1951 (before plant startup) to determine the concentrations of radioactive materials in a 1,200 square mile area outside the plant. Included in this area are parts of Aiken, Barnwell, and Allendale counties in South Carolina, and Richmond, Burke, and Screven counties in Georgia. This surveillance determines the magnitude and origin of any radioactivity above natural levels. Measured concentrations of radionuclides in air, water, and milk are compared with the maximum permissible concentrations (MPC) recommended by the International Commission on Radiological Protection (ICRP), or the daily intake guides recommended by the Federal Radiation Council (FRC).

Sensitive instruments, which can detect traces of radioactive material far below concentrations of hazard significance, are used to determine radioactivity in the environs. Plant-released radioactivity cannot be readily distinguished from weapons-tests fallout, and both are included in the reported concentrations. Maximum and minimum values given are for individual samples collected during the report period.

[6] Summarized from "Effect of the Savannah River Plant on Environmental Radioactivity, Semiannual Report, January–June 1966," DPST–66–30–2.

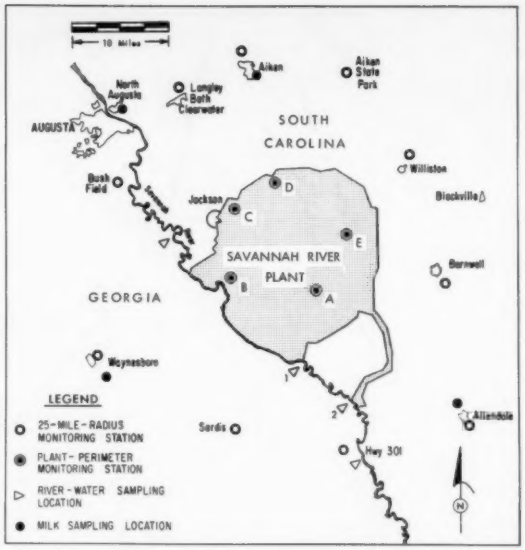

Figure 5. Environmental sampling locations, Savannah River Plant

Atmospheric monitoring

Concentrations of radioactive materials in the atmosphere were measured by weekly analyses of air filters collected at five monitoring stations near the plant perimeter and 10 stations around a circle of about 25 miles radius from the center of the plant (figure 5). Deposition rates of radioactive material at each station were also determined by monthly analyses of rain-water ion exchange columns (fallout collectors). The monitoring stations are spaced so that a significant release of airborne activity by SRP would be detected regardless of the prevailing wind. All stations operate continuously. Four additional air monitoring stations at Savannah and Macon, Georgia, and at Columbia and Greenville, South Carolina, are so distant from SRP that the effect of SRP operations is negligible; they are reference points for determining background activity levels (figure 6). This system permits comprehensive surveillance of atmospheric radioactivity and also makes it possible to differentiate between test fallout and SRP releases.

The small amount of filterable beta radioactivity released to the atmosphere, primarily from the fuel separations areas, was obscured by fallout from nuclear weapons tests. The

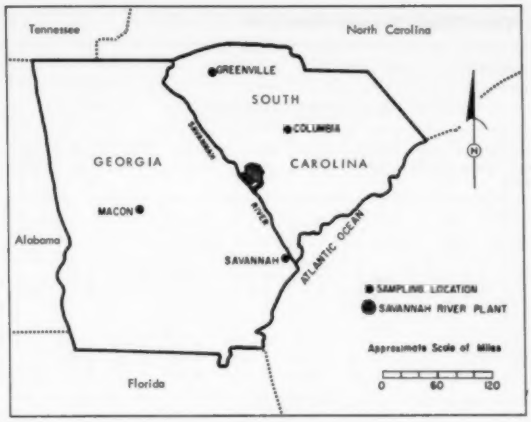

Figure 6. Distant air monitoring stations Savannah River Plant

influence of the weapons tests which resumed in September 1961 is shown in figure 7. The rises in early 1964, 1965, and 1966 were the result of the anticipated spring increases in the mixing of stratospheric debris into the troposphere. The Chinese nuclear tests conducted in May 1965 and May 1966 contributed to the airborne radioactivity during June of both years.

Radioactivity in air, determined from filter analyses, is shown in table 8. The January to June 1966 concentrations of filterable beta radioactivity (0.12 pCi/m^3) and alpha radioactivity (0.0008 pCi/m^3) in air were 0.1 and 2.0 percent of the respective MPC's. Tritium oxide concentrations in air, at the plant perimeter and at the 25-mile stations, did not exceed 1.1 percent of the MPC. Iodine–131 concentrations in routine air samples were less than 0.02 pCi/m^3, the lower detection limit, throughout the period.

Deposition of fallout during the first half of 1966 totaled 96.1 nCi/m^2 at plant perimeter locations and 69.5 nCi/m^2 at 25-mile-radius locations; comparable values for the last half of 1965 were 3.9 and 3.5 nCi/m^2. Fallout from the Chinese weapons test (primarily short-lived barium-lanthanum–140) accounted for the large increase. Beryllium–7, a radionuclide continuously being produced in nature by cosmic interactions in the upper atmosphere, was a measurable component in environmental radioactivity; the average deposition, 10.8 nCi/mi^2, was about the same as during July through December 1965. Deposition at each sampling location is presented in table 9.

Vegetation

Radioactive contamination of growing plants may result from deposition on foliar surfaces or absorption of radioactive materials from the soil.

Grass samples were collected at seven locations along the plant perimeter and at nine other locations along a 25-mile-radius route. (These are not designated on figure 5.) Samples from each quadrant of the plant and of the surrounding area were composited for monthly analysis. Radionuclides in grass samples were from fallout. Alpha-particle emitters averaged 0.2 pCi/g at the plant perimeter and 25-mile-radius locations as compared to 0.1 pCi/g during the last half of 1965; gamma-

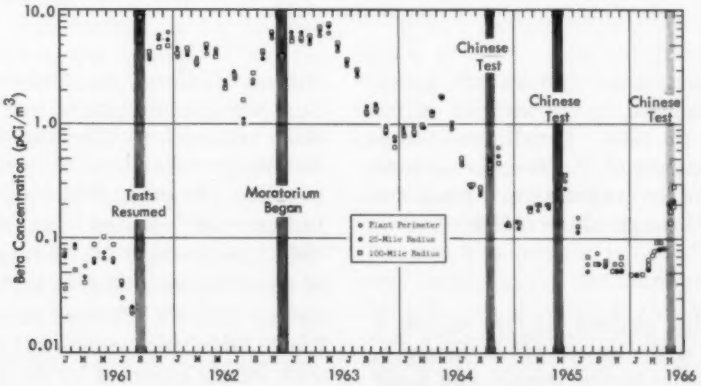

Figure 7. Influence of weapons tests

Table 8. Radioactivity in air, Savannah River Plant, January–June 1966

Filter analysis	Average concentrations (pCi/m³)															
	Plant perimeter locations						25-mile-radius locations									
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bushfield	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Alpha-particle emitters [a] (multiply by 10^{-3})																	
Maximum	2.2	2.2	2.3	1.9	2.0		2.7	2.2	1.6	3.0	1.5	2.2	1.4	1.8	2.6	2.2	
Minimum	0.3	0.6	0.3	0.3	<0.3		<0.3	<0.3	0.3	<0.3	0.3	0.5	0.5	0.4	0.4	0.3	
Average	0.8	1.0	0.9	0.8	0.7	0.8	0.9	0.7	0.7	0.8	0.8	0.9	0.8	0.9	0.9	0.7	0.8
Nonvolatile beta-particle emitters [b]																	
Maximum	0.30	0.26	0.27	0.28	0.27		0.35	0.31	0.49	0.34	0.29	0.36	0.34	0.32	0.25	0.30	
Minimum	0.04	0.04	0.04	0.04	0.04		0.03	0.04	0.05	0.04	0.03	0.04	0.04	0.05	0.02	0.02	
Average	0.12	0.12	0.11	0.12	0.12	0.12	0.14	0.12	0.14	0.12	0.11	0.12	0.11	0.12	0.12	0.11	0.12
Specific radionuclides (averages)	Composite sample						Composite sample										
Cesium-137	0.01						0.01										
Cerium-141, 144	0.03						0.02										
Ruthenium-103, 106	0.01						0.01										
Zirconium-niobium-95	<0.003						<0.003										
Manganese-54	<0.003						<0.003										
Beryllium-7	0.03						0.04										

[a] Sensitivity of analysis—3.0×10^{-4} pCi/m³.
[b] Sensitivity of analysis—0.006 pCi/m³.

Table 9. Total fallout deposited, Savannah River Plant, January–June 1966

Radionuclide	Fallout deposition (nCi/m²)															
	Plant perimeter locations						25-mile-radius locations									
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bushfield	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Alpha particles [a]	2.39	2.97	5.79	2.13	2.43	3.36	1.62	2.47	1.74	2.82	2.59	4.32	0.93	2.08	2.43	2.16	2.32
Beryllium-7	11.04	14.20	12.39	12.55	13.43	12.74	8.11	4.21	8.45	8.96	12.24	9.11	4.97	9.03	8.07	11.97	8.49
Manganese-54	0.15	0.15	0.19	0.12	0.15	0.15	0.08	0.15	0.08	0.12	0.19	0.15	0.15	0.15	0.15	0.08	0.12
Strontium-89	3.13	4.17	9.57	4.55	7.84	5.87	2.35	2.59	7.80	7.37	5.21	2.97	3.24	4.48	3.67	2.39	4.21
Strontium-90	0.97	1.20	1.35	1.24	1.78	1.31	0.77	1.24	1.39	1.62	1.54	1.24	0.97	1.47	1.20	2.16	1.35
Zirconium-niobium-95	5.17	1.93	10.96	3.94	9.53	6.29	2.97	3.24	5.79	4.90	2.93	8.57	3.63	2.86	1.43	3.90	4.01
Ruthenium-103, 106	9.84	8.11	8.92	8.69	16.21	10.34	6.14	8.30	15.25	15.52	7.80	8.96	8.69	13.05	3.59	12.89	10.27
Iodine-131	13.36	11.73	11.54	10.89	19.65	13.43	6.76	11.16	22.62	16.75	9.84	10.42	12.81	15.48	4.94	9.34	12.00
Cesium-137	1.97	1.47	1.47	1.54	1.85	1.66	1.39	1.70	2.08	2.08	2.08	1.66	1.27	1.74	1.39	1.81	1.74
Barium-lanthanum-140	32.73	45.93	49.56	41.07	81.06	50.06	14.01	17.41	48.33	42.46	27.14	25.78	18.57	30.15	14.09	56.78	29.49
Cerium-141, 144	6.18	4.63	8.69	5.25	10.42	7.03	4.25	4.79	9.92	8.53	6.48	6.95	5.17	6.99	2.39	6.33	6.18

[a] Multiply by 10^{-3}.

ray activities averaged 51 and 38 pCi/g, respectively, as compared to 22 and 18 pCi/g for the last half of 1965. Beryllium–7 comprised about 40 percent of the average gamma radioactivity found on vegetation during the period January through June 1966.

Milk

Milk was sampled at four dairies within a 25-mile radius of SRP, as shown in figure 5. Some samples were collected weekly and some biweekly. These samples were analyzed for tritium, radiocesium, and radioiodine. Strontium–90 determinations were made quarterly. Milk produced in the area and sold by major distributors was also analyzed for these radionuclides. Results from analyzing milk for radioactivity during January through June 1966 are in table 10. Average concentrations of three radionuclides in milk (47 pCi/liter for cesium–137, 26 pCi/liter for strontium–90, and 7 pCi/liter for iodine–131) were consistent with values reported by the U.S. Public Health Service for most sections of the United States

Table 10. Radioactivity in milk from local dairies, Savannah River Plant, January–June 1966

Location of local dairies	Concentration (pCi/liter)											
	Tritium [a]			Strontium-90 [b c]		Iodine-131 [d]			Cesium-137 [e]			
	Maximum	Minimum	Average	March 1966	June 1966	Maximum	Minimum	Average	Maximum	Minimum	Average	
Aiken	3,000	<3,000	<3,000	23	26	26	<5	6	90	<30	54	
Allendale	8,500	<3,000	<3,000	22	30	56	<5	11	118	<30	56	
North Augusta	19,000	<3,000	3,000	25	26	44	<5	6	61	<30	46	
Waynesboro	9,000	<3,000	<3,000	NS	24	27	<5	6	51	<30	37	
Major distributors	[f] 7,000	<3,000	<3,000	28	26	31	<5	7	57	<30	43	

[a] Sensitivity of analysis—3,000 pCi/liter.
[b] Sensitivity of analysis—1.0 pCi/liter.
[c] Strontium-90 determininations were made quarterly.
[d] Sensitivity of analysis—5.0 pCi/liter.
[e] Sensitivity of analysis—30 pCi/liter.
[f] Milk produced in local dairies, but sold by major distributors.
NS, no sample collected.

during the first half of 1966. Tritium in local milk, when present, is assumed to be associated with plant operations. The average tritium level was less than the sensitivity of the analysis, which allows detection of concentrations of 3.0×10^3 pCi/liter (1 percent of the MPC for water).

Food

Radioanalysis of farm produce collected during 1965 was completed during the first half of 1966. More than 40 samples representing 4 food categories (fruit, grain, leafy vegetables, and poultry) were collected during the harvest season at 14 localities in the 6 counties surrounding SRP (not shown on figure 5). With the exception of grains, all foods were prepared for analysis in a manner similar to that used to prepare them for eating. Peelings, seeds, and other nonedible parts were removed. Wheat, containing the whole grains only, and oats, containing both grains and husks, were processed unwashed. Gamma-ray spectrometry was used to analyze samples for cerium–144, ruthenium–103, ruthenium–106, cesium–137, manganese–54, and zirconium-niobium–95. Radiostrontium and alpha radioactivity were determined by radiochemical analysis. SRP contributions to the levels of radioactivity in foods were so low in 1965 as to be indistinguishable from weapons-test fallout.

Algae and fish in Savannah River

Weekly samples of fish, predominantly bream, and indigenous algae, primarily green (*Vaucheria*) and blue-green (*Phormidium*), were collected upstream from, adjacent to, and downstream from the Savannah River Plant. Determination of radionuclides in algae is important because algae concentrate certain radionuclides and also because of the role of algae in the food chain of aquatic organisms. Concentrations of beta-particle emitters in algae and fish adjacent to and downstream from SRP indicate some minor contribution by SRP. Although measurably higher than similar material collected at the control station 3 miles upstream from SRP, the slight increase is of no biological significance.

Specific radionuclide analyses were made on algae and fish collected from the Sanvannah River. Radiocesium and radiostrontium were found consistently in river algae; whereas cerium–141, cerium–144, chromium–51, zirconium-niobium–95, manganese–54, zinc–65, and cobalt–60 were detected less frequently. Also, radiostrontium (maximum, 45 pCi/g, wet weight) was detected in bone tissue of river fish, and radiocesium (maximum, 26 pCi/g, wet weight) was detected in the flesh tissue. Radiozinc and phosphorus–32 were detected less frequently in these tissues. The maximum concentrations of phosphorus–32 detected in bone and

flesh tissues of river fish were 313 pCi/g, and 30 pCi/g, respectively.

Water monitoring

The plant site is drained by five streams which flow several miles through the reservation before reaching the river (figure 8). In January 1965, the Beaufort-Jasper Water Authority began operation of a new treatment facility to furnish drinking water, partially supplied from the Savannah River, to most of Beaufort County, S.C. Water is supplied through a new canal from the river at a location about 90 miles below the SRP. The city of Savannah also supplements its domestic well water supply with river water during periods of peak demand.

Communities near SRP get domestic water from deep wells or surface streams. Public water supplies from 14 surrounding towns were collected and analyzed monthly. There was no evidence that SRP contributed radioactivity to drinking water supplies; concentrations of alpha radioactivity (1.3 pCi/liter) and beta radioactivity (6 pCi/liter) were essentially the same as those observed before plant startup.

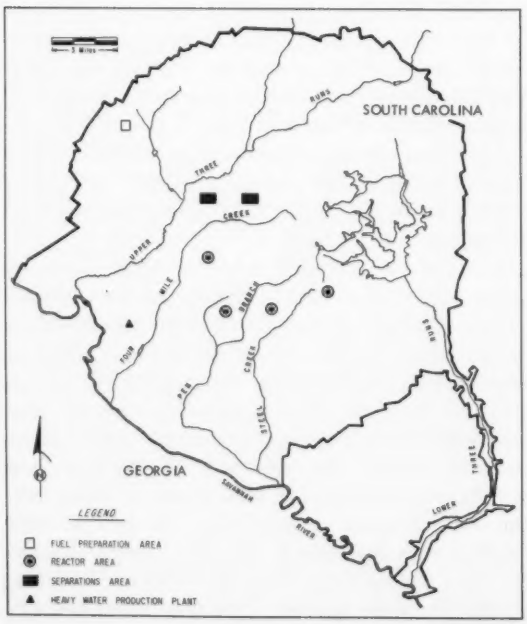

Figure 8. SRP production areas and effluent streams

River water, analyzed weekly, was sampled continuously at four locations, as shown in figure 5. Average concentrations of specific radionuclides found in river water during January–June 1966 are shown in table 11.

Table 11. Average concentration of radionuclides in Savannah River water, Savannah River Plant January–June 1966

Radionuclide	Concentration (pCi/liter)			
	Sensitivity of analysis	Control (3 miles upstream from plant)	Highway 301 (10 miles downstream from plant)	Percent MPC at Highway 301
Tritium-3	600	1,100	11,000	3.7
Chromium-51	4.3	<4.3	28.9	0.004
Manganese-54	0.4	<0.4	<0.4	<0.001
Cobalt-60	1.4	<1.4	<1.4	<0.01
Zinc-65	1.1	<1.1	<1.1	<0.01
Strontium-89	0.3	<0.3	0.8	—
Strontium-90	0.01	1.1	1.8	—
Zirconium-niobium-95	0.5	<0.5	0.6	0.003
Ruthenium-103, 106	3.2	<3.2	<3.2	<0.10
Iodine-131	0.5	<0.5	0.3	—
Cesium-134, 137	0.6	<0.6	2.1	0.10
Barium-lanthanum-140	1.6	<1.6	1.8	0.03
Cerium-141, 144	2.5	<2.5	2.9	0.10
Neptunium-239	0.9	1.1	2.6	0.01

Cesium–137, strontium–89, strontium–90, chromium–51, tritium, and trace amounts of cerium–141, zirconium-niobium–95, and iodine–131, released mainly from reactor areas, were the radionuclides of SRP origin detectable in river water at the downstream location. Average concentrations of all radionuclides found in river water during January through June 1966 were only small fractions of the permissible concentrations. The tritium concentrations in finished water collected from the Beaufort-Japser Water Plant averaged 5,600 pCi/liter (1.9 percent MPC) during the 6-month report period.

Tritium, a beta-ray emitter and the most abundant radionuclide released to the river, is produced by neutron irradiation of heavy-water moderator in the reactors. Chromium–51, the second most abundant radionuclide released to the river, is produced by neutron irradiation of stable chromium (a component of the stainless steel used in reactor parts). Tritium and chromium–51 are among the least dangerous of all radionuclides because neither concentrates in body tissues. The tritium and

chromium–51 concentrations in river water averaged 3.7 and 0.004 percent MPC, respectively.

Environmental gamma radiation levels

Monthly measurements of environmental gamma radiation were made with thermoluminescent dosimeters. January through June 1966 data (shown in table 12) are considered more representative than previous data obtained by monthly spot readings using portable Geiger-Mueller survey instruments.

Summary

The quantity of radioactive waste released by the Savannah River Plant to its environs during the period January through June 1966 was, for the most part, too small to be distinguished from natural background radiation or was obscured by worldwide fallout from nuclear weapons testing. Fallout from the Chinese nuclear test on May 9, 1966, was detected at SRP.

Beta radioactivity in air, which showed no relationship with plant operations, was about one-half that for the same period of 1965. Radioactive materials in fish flesh continued to be far below levels considered significant from a health standpoint. The average concentration of radionuclides in river water did not exceed 3.7 percent of the maximum permissible concentrations.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July–December 1961	September 1962
Calendar year 1962	August 1963
Calendar year 1963	August 1964
January–June 1964	February 1965
July–December 1964	August 1965
January–June 1965	February 1966
July–December 1965	August 1966

Table 12. Environmental gamma radiation, Savannah River Plant, January–June 1966

	Exposure rate (mR/day)																
	Plant perimeter locations						25-mile-radius locations										
	A	B	C	D	E	Average	Aiken Airport	Aiken State Park	Allendale	Barnwell	Bushfield	Langley	Sardis	Waynesboro	Williston	Highway 301	Average
Maximum	0.30	0.36	0.35	0.31	0.41		0.32	0.22	0.24	0.26	0.30	0.26	0.31	0.25	0.32	0.27	
Minimum	0.25	0.26	0.26	0.24	0.25		0.21	0.19	0.21	0.20	0.23	0.20	0.23	0.17	0.21	0.12	
Average	0.27	0.29	0.30	0.27	0.29	0.28	0.25	0.20	0.22	0.23	0.27	0.23	0.26	0.22	0.25	0.22	0.24

4. Shippingport Atomic Power Station January–June 1966[7]

Duquesne Light Company
Shippingport, Pennsylvania

The Shippingport Atomic Power Station is operated for the Atomic Energy Commission by the Duquesne Light Company. The plant site is located near Shippingport, Pennsylvania, along the Ohio River about 25 miles northwest of Pittsburgh (figure 9).

The pressurized water reactor with Core 1 ("seed and blanket" design) achieved full power on December 23, 1957, and has operated continuously except for shutdowns which were necessary for maintenance and "seed" refueling. In February 1964, the reactor was shutdown for the replacement of Core 1 with Core 2, the decontamination of the primary system, and the commencement of other associated reactor plant modifications. The reactor remained shut down until April 1965, at which time operations were resumed.

An environmental monitoring program was started 2 years before plant startup to determine the background levels of radioactivity in

[7] Summarized from "Environmental Radioactivity at the Shippingport Atomic Power Station for the First Half of 1966," PNRO–SMD–139.

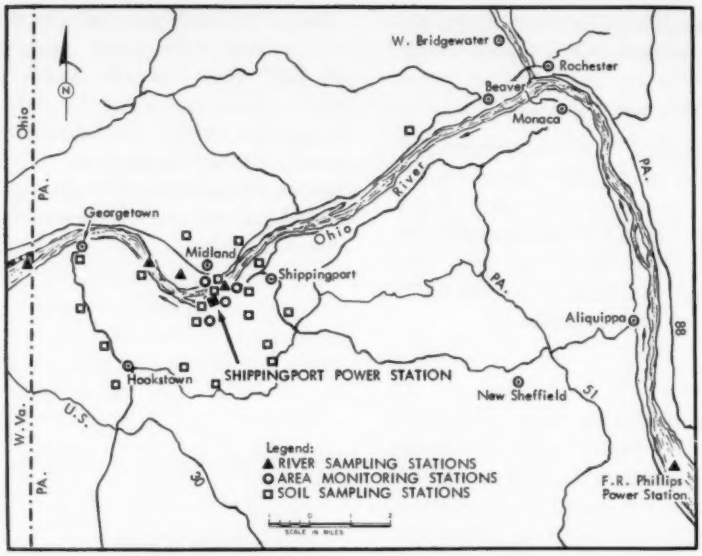

Figure 9. Shippingport power station sampling locations

the environment. This program was continued after plant startup to ensure that radioactive wastes discharged from normal plant operations do not cause significant changes in these levels in the plant environment.

In January 1966, environmental monitoring program was revised in the following manner:

1. fallout and precipitation sampling at three locations surrounding the station was reduced to one sample taken at one onsite location,
2. the continuously recording beta-gamma radiation monitors and the continuously recording airborne particulate monitors for radioactivity situated at three locations surrounding the station were eliminated. For monitoring significant airborne releases of radioactivity in case of an accident, 12 film badges were located surrounding the station and changed on a quarterly basis,
3. the sampling of river sediment upstream and downstream from the station's outfall was commenced on a quarterly basis.

Liquid radioactive waste disposal

The concentration limits for the discharge of radioactive wastes at Shippingport are based on a knowledge of the radionuclide mixture making up the waste and on the radiation protection standards of Title 10, Code of Federal Regulations, Part 20, AEC Manual, Chapter 0524 and Chapter 4, Article 433 of the Rules and Regulations, Commonwealth of Pennsylvania Department of Health. The discharge of tritium, which is less hazardous than fission and activated corrosion products, is controlled separately using the prescribed AEC concentration guides in each case. The liquid effluent from the plant radioactive waste disposal system is carefully monitored before, during, and after release to the Ohio River to ensure that the concentration limits recommended by the above regulations are not exceeded.

The liquid radioactive wastes discharged during the first half of 1966 are summarized in table 13 and 14. The monthly average concentrations of gross radioactivities shown in table 13 include normal background radioactivity and are calculated after total radioactive waste discharges are diluted in the condenser cooling water effluent channel. The maximum total discharge in 1 day during the first half of 1966 was 1.27 millicuries.

Table 13. Total radioactive waste, exclusive of tritium, discharged into the Ohio River, Shippingport Atomic Power Station, January–June 1966

Period	Total radioactivity (mCi)	Average radioactivity (mCi/day)	Average radioactivity in effluent channel (pCi/liter)
January	5.77	0.186	5.82
February	6.09	0.218	5.14
March	4.41	0.142	2.94
April	3.77	0.126	2.78
May	4.39	0.142	1.88
June	2.81	0.094	1.05
Summary	27.24	0.150	2.71

Table 14 is a summary of the tritium that was discharged into the Ohio River, the monthly average tritium radioactivity in the hold-up tanks prior to discharge, and monthly average concentration of the radioactive waste in the effluent channel after dilution with the condenser cooling water. The maximum quantity of tritium discharged in 1 day during the first half of 1966 was 297 millicuries.

Table 14. Tritium released to Ohio River, Shippingport Atomic Power Station, January–June 1966

Period	Total tritium activity (mCi)	Average tritium activity (mCi/day)	Average tritium activity in hold-up tanks (10^3 nCi/liter)	Average tritium activity in effluent channel (nCi/liter)
January	405	13.1	2.81	0.65
February	608	21.7	2.87	0.85
March	1,392	45.0	7.28	2.11
April	1,517	50.5	8.18	1.91
May	2,253	72.5	10.13	1.60
June	2,764	92.0	12.52	1.72
Summary	8,939	49.4	7.62	1.54

Automatic samplers are installed at the station's river water influent and effluent to collect water samples continuously for comparative purposes. Since the effluent sampler was inoperative from January through May 1966 daily grab samples were collected. Weekly composites of the daily grab samples and continuous samples were analyzed for gross beta and gross alpha radioactivities in the suspended and dissolved solids. The potassium–40 radioactivity in the total solids of these samples was also measured. No significant difference was observed between the average alpha, beta, and potassium–40 radioactivity in the influent and effluent samples. The results of these analyses are shown in table 15.

Table 15. Gross radioactivity in the Ohio River, Shippingport Atomic Power Station, January–June 1966

Type of radioactive material	Average radioactivity of influent samples (pCi/liter)			Average radioactivity of effluent samples (pCi/liter)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
Alpha radioactivity						
Suspended solids	28.10	0.01	1.59	4.66	0.02	0.44
Dissolved solids	6.56	0.14	0.65	4.09	0.23	0.54
Total solids	29.23	0.30	2.24	5.10	0.30	0.97
Beta radioactivity						
Suspended solids	58.95	0.19	8.30	19.20	0.29	5.71
Dissolved solids	16.57	1.59	5.91	12.06	0.93	6.22
Total solids	45.27	4.41	14.20	25.26	2.00	11.93
Potassium-40						
Total solids	6.40	2.70	4.59	6.60	2.70	4.59

Atmospheric release of radioactive materials

During the first half of 1966, a total of 30.4 mCi of xenon–133 was released at Shippingport at concentrations less than the MPC of 3 x 10^{-5} pCi/m^3. The incinerator, which is used for burning combustible contaminated waste, was not operated.

Environmental monitoring

Twelve beta-gamma-ray-sensitive film badges were posted around the station boundary to determine external radiation exposure from environmental radiation and from station operations. However, due to the effect of temperature and humidity, reliable results were not obtained from the film badges during this report period. For this reason, no data on radiation levels are presented.

River sediment samples were collected from the Ohio River once each calendar quarter upstream and downstream from the station's liquid waste outfall. These samples were gamma-counted and quantified assuming all detected radioactivity to be due to cobalt–60, which is the major constituent of radioactive contamination at the station. Gross radioactivity in the sediment for the first and second calendar quarters were, respectively, 11.11 and 9.07 pCi/g upstream and 7.29 and 9.87 pCi/g downstream from the outfall. These results indicate that there was no appreciable increase of radioactivity in the river sediment as the result of the station's discharges of radioactive contaminated liquid wastes.

Radioactive fallout was collected in a pot at one onsite location and analyzed weekly for alpha and beta radioactivity. The average first quarter, second quarter and first half of 1966 results are depicted in table 16.

Table 16. Radioactivity in fallout, Shippingport Atomic Power Station, January–June 1966

Period	Fallout deposition rate ($nCi/m^2 \cdot month$)	
	Alpha radioactivity	Beta radioactivity
January–March	0.22	4.79
April–June	0.60	37.27
January–June	0.41	21.03

Summary

During the first half of 1966, measurements of radioactivity were made in the Ohio River and in the vicinity of the Shippingport Atomic Power Station. The results of these measurements indicate that the radioactive material released by the power station into the Ohio River did not result in a significant change in the naturally occurring radioactivity in the environment.

Recent coverage in *Radiological Health Data and Reports:*

Period	Issue
July 1962–June 1963	March 1964
July–December 1963	November 1964
Calendar year 1964	August 1965
January–June 1965	February 1966
July–December 1965	July 1966

Section V. Technical Notes

REPORTED NUCLEAR DETONATIONS, JANUARY 1967

During January 1967, two U.S. nuclear tests at the Nevada Test Site were announced by the Atomic Energy Commission.

On January 19, and January 20, 1967, underground nuclear tests were conducted. Both tests were in the low-intermediate yield range (equivalent force of 20 to 200 kilotons of TNT).

SYNOPSES

Synopses of reports, incorporating a list of key words, are furnished below in reference-card format for the convenience of readers who may wish to clip them for their files.

RADIONUCLIDE LEVELS IN MILK, TOTAL DIET, AND HUMAN BONE COMPARED TO FEDERAL RADIATION COUNCIL ESTIMATES, 1965, AND 1966 ESTIMATES. *U.S. Public Health Service, National Center for Radiological Health. Radiological Health Data and Reports, Vol. 8, February 1967, pp.*

Estimates of the levels of fallout radionuclides in environmental media and in human bone expected from 1963 through 1965 have been made by the Federal Radiation Council. The 1965 observed values are compared with the FRC predictions and 1966 levels are estimated using the approach proposed by the Federal Radiation Council. The observed radionuclide levels are in agreement with the prediction made by the Radiation Council. The observed levels and the predicted levels of radioactivity in food over the next several years are too small to justify protective action to limit the dietary intake of radionuclides.

KEY WORDS: bone, calcium, cesium–137, diet, iodine–131, milk, Pasteurized Milk Network, protection guides, radiation, strontium–89, strontium–90.

STRONTIUM–90 DIETARY INTAKE ESTIMATES BASED ON FRACTIONAL INTAKES DUE TO MILK. *R. O. Grundy. Radiological Health Data and Reports, Vol. 8,* February 1967, pp. 73–77.

Strontium–90 dietary intake estimates were made for the Institutional Total Diet Sampling Network based upon Pasteurized Milk Network concentrations. Approaches based upon milk-to-total-diet ratios of strontium–90 and strontium units were considered. The approach based upon strontium units yielded the best estimates of ITDSN monthly average and maximum strontium–90 intakes on a Network basis for the population groups involved.

KEY WORDS: Calcium, diet, Institutional Total Diet Sampling Network, intakes, milk, Pasteurized Milk Network, strontium–90, strontium unit.

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SYMBOLS, UNITS, AND EQUIVALENTS

Symbol	Unit	Equivalent
BeV	billion electron volts	GeV
Ci	curie	3.7×10^{10} dps
cm	centimeter(s)	0.394 inch
cpm	counts per minute	
dpm	disintegrations per minute	
dps	disintegrations per second	
eV	electron volt	1.6×10^{-12} ergs
g	gram(s)	
GeV	giga electron volts	1.6×10^{-3} ergs
kg	kilogram(s)	1,000 g = 2.205 lb
km^2	square kilometer(s)	
kVp	kilovolt peak	
m^3	cubic meter(s)	
mA	milliampere(s)	
mCi/mi^2	millicuries per square mile	0.386 nCi per square meter (mCi/km^2)
MeV	million (mega) electron volts.	1.6×10^{-6} ergs
mg	milligram(s)	
mi^2	square mile(s)	
ml	milliliter(s)	
mm	millimeter(s)	
nCi/m	nanocuries per square meter.	2.59 mCi per square mile
pCi	picocurie(s)	10^{-12} curie = 2.22 dpm
R	roentgen	
rad	unit of absorbed radiation dose.	100 ergs per gram

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

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